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CHEMISTRY TRENDS IN ATLANTIC CANADA LAKES

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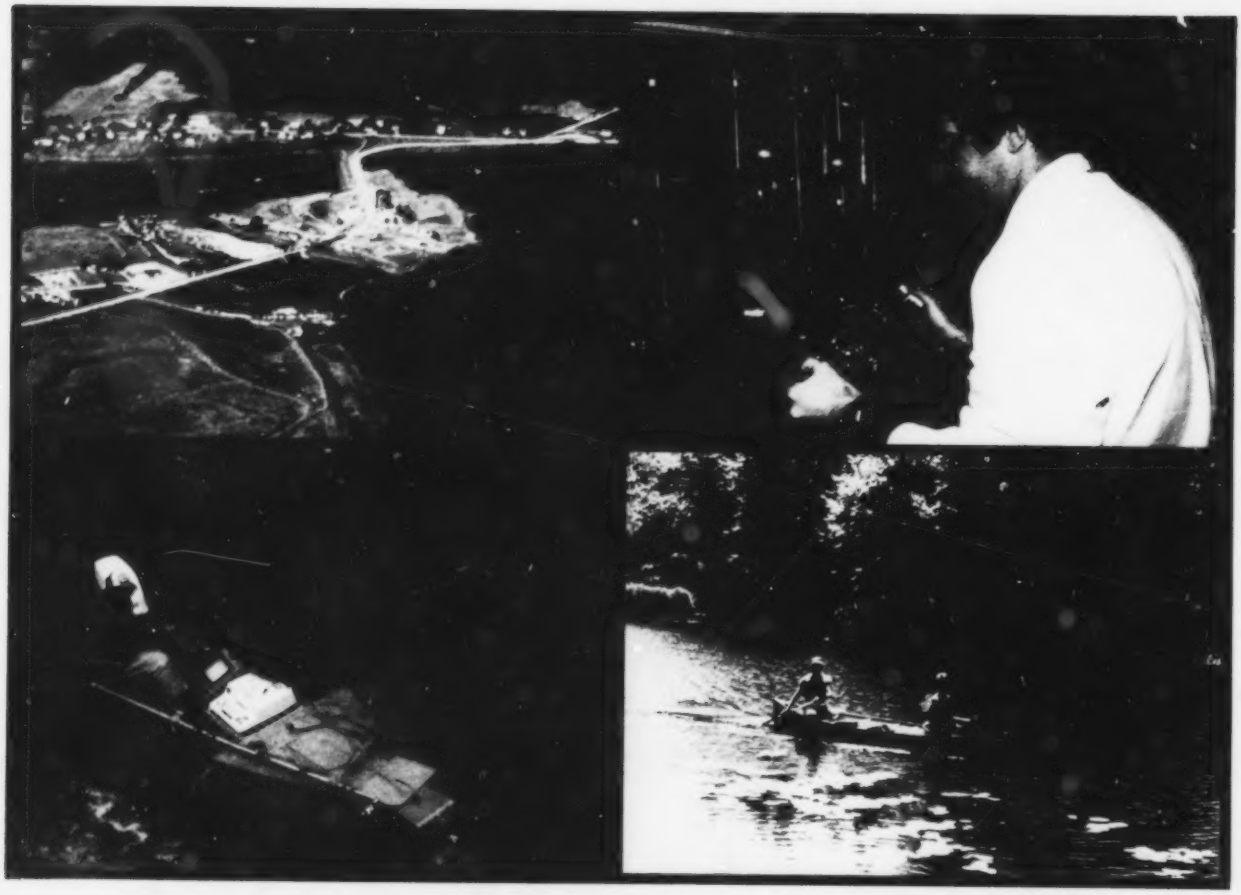

Canada

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ATLANTIC REGION
WATER QUALITY BRANCH
MONCTON, NEW BRUNSWICK

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Chemistry Trends in Atlantic Canada Lakes

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ABSTRACT

Thirty nine lakes from southwest Nova Scotia and 33 from all over Newfoundland were sampled semi-annually from the Spring of 1983. A number of acidification related water chemistry variables were evaluated for trends using non-parametric techniques. Results showed that pH increased in almost half of Newfoundland lakes. Acid neutralization capacity (ANC) increased in one third of Nova Scotia lakes and in six of the Newfoundland sites. Despite the strong evidence from pH and ANC which suggested a reduction in acidification effect, only a few lakes in Nova Scotia showed decreases in sulfate (SO_4^{-2}). Moreover, base cation concentrations also did not seem to vary much over time.

The improvements which were measured in water chemistry tend to corroborate with decreases in SO_4^{-2} deposition measured at a number of CAPMoN sites in the region.

RESUME

Nous avons échantillonné 39 lacs dans le sud-ouest de la Nouvelle-Ecosse, ainsi que 33 de l'ile de Terre Neuve depuis le printemps de 1983. Utilisant des techniques non-paramétriques, nous avons tenté de calculer s'il y avait des changes dans un nombre de variables chimiques aquatique qui étaient mesurées. Nos résultats démontrent une augmentation du pH dans presque la moitié des lacs de Terre Neuve. La capacité de neutralisation d'acide (CNA) a aussi augmenté dans le tiers des lacs échantillonnés en Nouvelle-Ecosse. Malgré les changements de pH et CNA détectés suggérant une diminution des effets de précipitations acides, quelque lacs seulement ont aussi démontré une diminution de sulfates dissous.

Malgré le manque de diminutions de concentration des sulfates dans les lacs, l'amélioration du pH et de la CNA correspond avec la diminution de sulfates mesurés dans les précipitations au Parc National Kejimkujik, situé en Nouvelle-Ecosse.

MANAGEMENT PERSPECTIVE

Data from a lake network set up to monitor trends in acid deposition effects in Atlantic Canada are analyzed. Data were collected from 1983 to 1989 in 39 lakes from Nova Scotia and 33 in Newfoundland. Trends of improving water quality were measured in 29 lakes in the region, worsening quality was shown at one site only, while 42 lakes showed no consistent trends. The changes in water quality occurred simultaneously with measured reductions in acid deposition.

The results confirm that as acid precipitation decreases in the region, the existing monitoring network allows us to measure the water quality improvements which are predicted by computer models.

PERSPECTIVE DU GESTIONNAIRE

Les données du réseau TADPA de la région Atlantique qui comprend 39 lacs de la Nouvelle Ecosse et 33 de Terre Neuve sont analysés. Entre 1983 et 1989, nous avons mesuré des améliorations de qualité d'eau dans 29 lacs. La qualité c'est rempiré dans un lac, et 42 n'ont pas démontré de changements. Durant la période étudiée, une diminution de déposition acides fut aussi mesurée.

Nos résultats confirment ceux des modèles géochimiques qui ont prédit des améliorations de qualité d'eau avec des réductions de pluies acides.

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INTRODUCTION

Atlantic Canada receives significantly higher than background levels of acidifying ions in precipitation (Sirois and Summer 1989). Clair and Whitfield (1983), using time-series analyses, showed that trends in sulfate increased and pH decreased in sensitive rivers of the area from 1968 to the late 1970's. In contrast, Green et al. (1986) using a variety of experimental statistical procedures on data from the same sites found that pH and sulfate (SO_4^{-2}) were relatively stable from the mid-1960's to the mid-80's. Part of the differences in interpretation was likely due to inappropriate analytical methods used in the laboratory analysis of samples, as well as differences in the time period studied. For example, SO_4^{-2} was measured using the methyl thymol blue method (WQB 1979) on most waters collected before 1981. Later work (Kerekes et al. 1984) eventually showed the method overestimates actual values due to interferences from natural organic acids. Another problem encountered was that the two end-point alkalinity approach (WQB 1979) with a detection limit of 0.5 $mg*L^{-1}$ was used on early samples. Many surface waters in Atlantic Canada, because of very low buffering capacities of soils and bedrock, have much lower concentrations than this, thus generating large numbers of censored values.

In recent years, major advances have occurred in both laboratory and statistical approaches. Since the early 1980's the ion chromatography (IC) (WQB 1985) and Gran titration approach (Gran 1952) have become common laboratory methods for SO_4^{-2} and acid neutralization capacity (ANC) respectively, so that the data accumulated are of higher quality. Secondly, important advances have occurred in trend detection techniques. Cluis (1988, 1989) and Loftis

(1991) have summarized a number of non-parametric approaches which require fewer restrictions to assess data sets for trends. A combination of improvements in the actual data, as well as its interpretation, now allow a more rigorous assessment of trends in freshwater chemistry.

There were measurable decreases in emissions of acidifying substances from the United States and Canada from 1980 to 1985 (RMCC 1990a), which were reflected in decreased SO_4^{-2} deposition in Nova Scotia from 1980 to 1987 (Sirois and Summers 1989, Underwood et al. 1989) and Newfoundland between 1982 and 1987 (Ryan et al. 1990). The estimated decrease in SO_4^{-2} was from 12 to 6 kg ha^{-1} $an.^{-1}$ in Newfoundland, but was much less precipitous in Nova Scotia. This report was prepared in order to see if the measured changes in precipitation chemistry could also be related to surface waters.

In 1983, the Inland Waters Directorate of Environment Canada began monitoring a number of lakes in Nova Scotia and Newfoundland using the improved analytical methods described above. Most of the lakes were selected in 1982 using historic survey data (Howell 1986). The sites, located away from human development or local pollution sites were clustered into groups based on water chemistry parameters related to acidification (Esterby et al. 1989, Clair and Esterby 1991). The clustering was used to allow comparisons of chemistry trends between similar sites, making interlake comparisons more relevant.

Many lakes in Atlantic Canada are low in dissolved inorganic ions compared to those from other locations, making them both more sensitive to acidification effects. Many also have high dissolved organic carbon levels which makes it more difficult to study trends in acidification. Not only does DOC itself tend to lower water pH from the dissociation of organic acids, but the organic anions so formed can then buffer the solution from mineral acids. In order

to quantify the changes in pH, ANC and other parameters with changes in acidifcation, the relationship between parameters was expressed following the electroneutrality principle where:

$$\sum C_b - \sum C_a = ANC = [HCO_3^-] + 2[CO_3^{-2}] + [OH^-] + [O_r^-] - [H^+] \quad (Equa.1)$$

C_b and C_a denote the sum of the base cations (Ca^{+2}, Mg^{+2}, K^+, Na^+) and acid anions (SO_4^{-2}, Cl^-) respectively, ANC is the acid neutralization capacity as measured using the Gran titration, HCO_3^- (bicarbonate) and CO_3^{-2} (carbonate) are measured as dissolved inorganic carbon (DIC) and estimated using pH (Stumm and Morgan 1981), OH^- (hydroxyl) and H^+ (hydrogen) are calculated from the pH measurement, and O_r is the organic anion component contributed to water from the breakdown of plant organic matter. Assuming that the organic anion contribution is independent of acid precipitation effects and thus will remain stable, changes in SO_4^{-2} which would reflect acid deposition variations, should then lead to changes in ANC and pH (Eq. 1). Changes in SO_4^{-2} deposition could also modify C_b, as acid deposition increases bedrock weathering, and thus can increase base cations (Killam 1982).

By using the information collected in the sampling program and analyzing it within an electroneutrality framework, we should thus better understand the causes of measured trends. The purpose of this report is then to describe and explain results of the trend analysis conducted on Environment Canada's Atlantic lake monitoring network from 1983 to 1989.

AREA AND METHODS

Water Sampling and Analysis

Monitoring of precipitation chemistry in the Atlantic Region was done at a number of sites (Vet et al. 1988), though the data have only been analyzed for trends at Kejimkujik National Park, in the western portion of the study area. A continuous trend of decreasing SO_4^{-2} deposition in precipitation was measured from 1979 to 1987 (RMCC 1990b). The situation was somewhat different for NO_3^{-2} deposition, as it seemed to increase slightly during the same period. However, overall deposition of acidifying anions showed a decrease at this site. Amounts of acidifying substances deposited in Newfoundland are approximately half those in Nova Scotia, due to the greater distance of this region from pollution sources. Though no trend analysis was done of Newfoundland data, other data (RMCC 1990b) also suggest that the same deposition changes which occurred in Nova Scotia were reflected there.

Since the spring of 1983, 72 sites have been sampled twice a year, during the spring and fall lake overturn periods in the two Atlantic Provinces (Figures 1 and 2). The lakes were chosen because their basin geology and geography make them most sensitive to acid precipitation and because of their low anthropogenic development (Howell 1986). In total, 42 of the lakes were located in national parks because of their protected condition which allows for long-term studies. The remaining sites were from non-protected areas which were needed for adequate geographical coverage. Appendix A and B describe the site location and chemistry.

The limnology of Atlantic Canadian lakes is well understood. Kerekes (1974) and Kerekes et al. (1982) have reported on limnological conditions of lakes in Terra Nova National

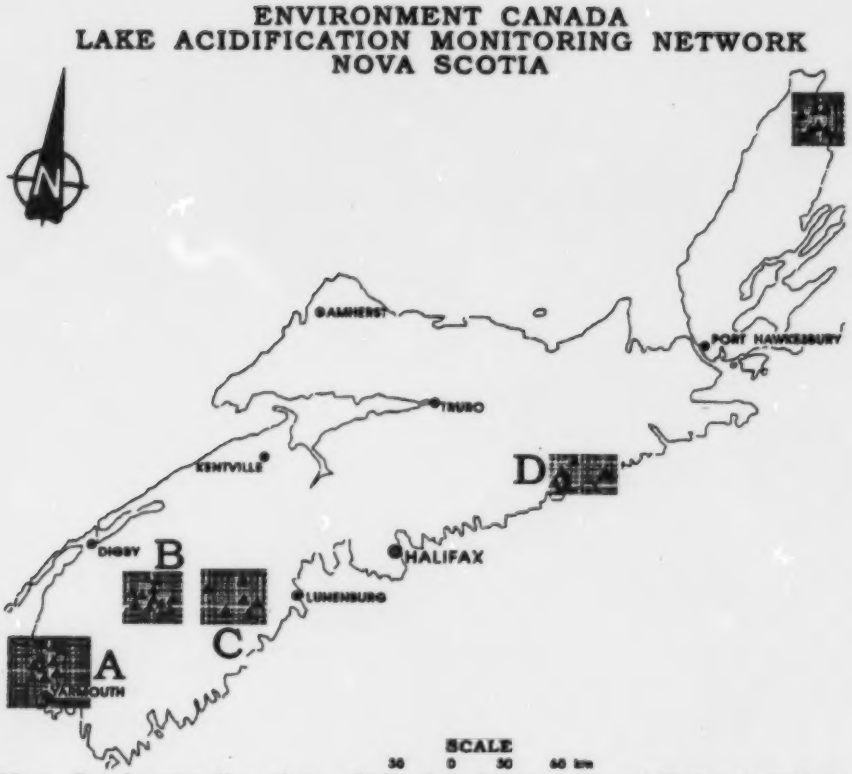

Figure 1 Location of Nova Scotia sampling sites. Only sites in areas A and B are described in this work (see Appendix A).

Park in eastern Newfoundland and at Kejimkujik National Park located in central Nova Scotia. Generally, most of the lakes sampled in the Environment Canada program are small glacial scours (Ehrman and Clair MS) and thus are shallow and well mixed in the spring and fall.

Sampling was conducted using a helicopter at most sites from the spring of 1983 to fall

1989. Sampling procedure involved manual collection of water at 30 to 50 cm depth from the surface. At randomly chosen sites, triplicate samples were collected to measure reproducibility. The samples were shipped to the Inland Waters regional laboratory in Moncton, N.B., where they were analyzed for major ions and other parameters using standard analytical methods (Anonymous 1984). Though not reported here, regular review of triplicate data showed most parameters were within ±10 % of the mean.

Sulfate (SO_4^{-2}) is the most important acidification parameter of surface waters of the region. It, as well as Cl^-, were measured using the ion chromatography (IC) method, which avoids colour interferences. Acid neutralization capacity (ANC), which is sometimes called alkalinity, was measured using the Gran (1952) approach. Calcium and magnesium were analyzed by atomic absorption spectroscopy and K and Na by flame photometry.

Dissolved organic carbon (DOC) is a major component of water chemistry of approximately half the lakes sampled. DOC is produced by soil, wetland and planktonic biological activities and is transported to water courses by hydrological processes. This parameter is thus an indicator of basin background processes which should only vary with climatic changes. For this study, we used colour measured using the platinum-cobalt relative scale as a surrogate for organic content. Values ranged from less than 5 units for clear waters, to greater than 100 for brownwaters draining bogs and other wetlands.

In Atlantic Canada, Cl^- is often found at high concentrations in surface waters due to seaspray contributed by the nearby ocean. As Cl^- is thought not to be involved in basin biological, geological or chemical processes, cations and anions contributed from seaspray were corrected for seasalt using this ion (Watt et al. 1979).

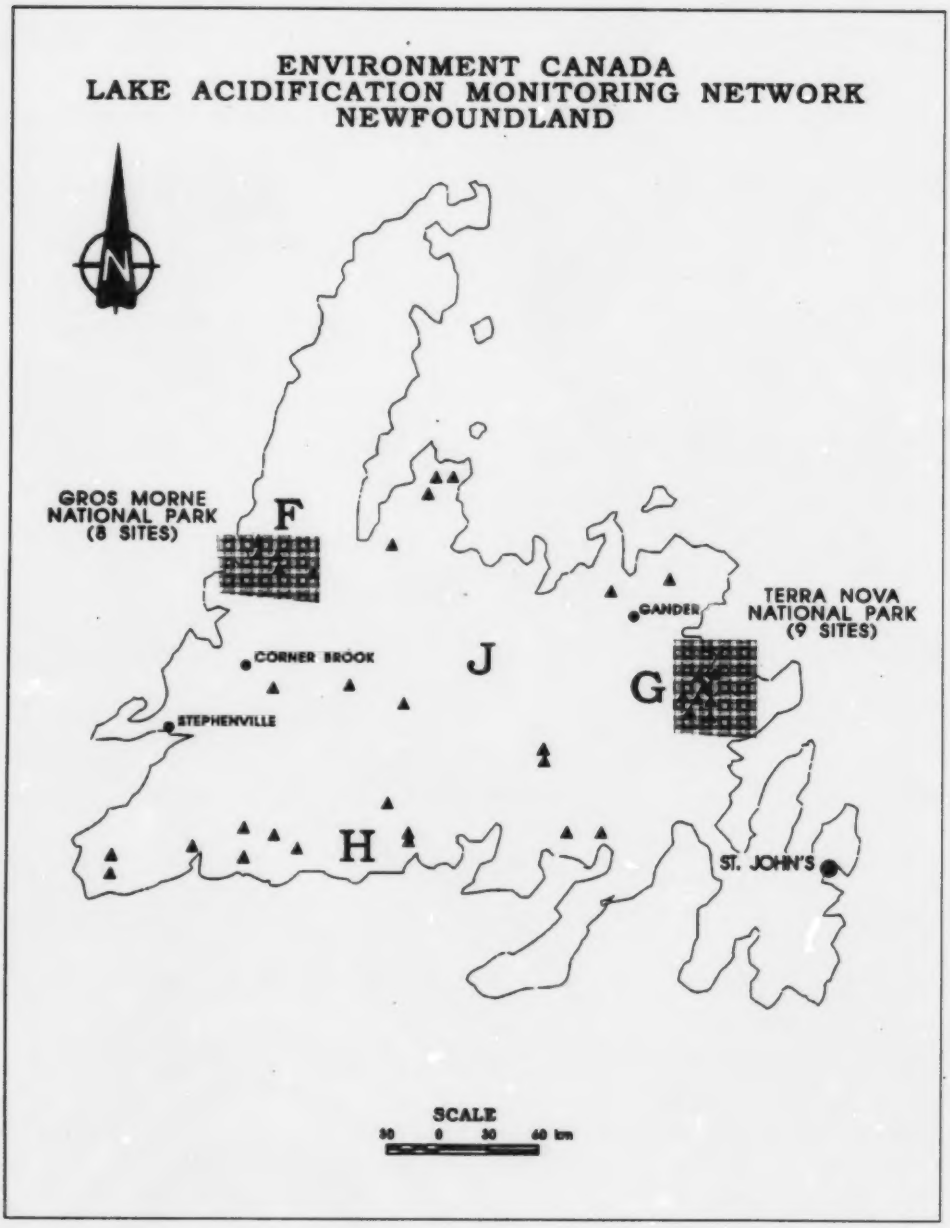

Figure 2 Location of Newfoundland sampling lakes.

Statistical Analysis

The lakes were clustered into groups based on the capacity of background conditions to influence water pH. This involved using the sum of base cations in water (C_b) an indicator of geological neutralization capacity, and organic anions, using the Oliver et al. (1983) estimator (A^-) to assess the importance of wetlands in generating organic acids (Clair and Esterby 1991). The clustering procedure produced five groups of lakes which were composed of: low C_b, low A^- sites (Cluster 1), moderate C_b, low A^- (Cl. 2), low C_b, moderate A^- (Cl. 3), high C_b, moderate A^- (Cl. 4) and moderate C_b, high A^- (Cl. 5) (Table 1). There were no high C_b, high A^- sites kept for this analysis. Trends in parameters within each cluster were then compared to each other to see if similar lakes from within and between the two Zones, Nova Scotia and Newfoundland, under study could be seen.

Table 1. Centroid water chemistry values values for each cluster of monitoring lakes. Parameter values are in $\mu eq*L^{-1}$ (from Clair and Esterby 1991). # indicates the number of total lakes in each cluster.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	C_b	A^-	C_b	A^-	C_b	A^-	C_b	A^-	C_b	A^-
value	40.0	28.2	95.6	32.2	74.1	60.0	179	47.1	81.9	94.
#	22		7		25		11		7	

Trend analysis was done on each parameter from each individual lake. Based on data characteristics, one of a series of non-parametric tests is used to analyze for trends in the data, as well as for seasonality and serial correlation (Markovian persistence). The trend tests selected

Table 2. Statistical methods used to analyze lake data for monotonic trends. (From Cluis et al. 1988).

Persistence	Seasonality	Test to be Used
No	No	Kendall
No	Yes	Kendall Seasonal
Yes	Yes	Hirsh and Slack
Yes	No	Spearman/Lettenmaier

from are shown in Table 2 (from Cluis et al. 1988). Persistence was calculated by analyzing the first to third order correlation coefficients of the data seriesand their associated standard deviations. There is no persistence if the first correlation coefficient (p1) is not significantly different from 0. There is Markovian persistence when p1 is significantly different from 0, and non-Markovian persistence when both p1 and the second order partial auto-correlation coefficient are significantly different from 0. A coefficient is significantly different from 0 if its value is at least twice its standard deviation. Further discussion of the use of the tests is found in Cluis et al. (1988). Due to the intensive nature of the sampling program, less than 1% of the sampling points were missing. These were replaced by temporal interpolation using calculated seasonal means (Cluis et al. 1989).

Seasonality in the data is assessed by comparing monthly means to see if they are significantly different from each other. If they are, then there is seasonality. After all data sets were analyzed, results showed that either the Kendall seasonal or the Spearman/Lettenmaier tests provided the best results for all cases studied. Trend analyses were carried out on pH and H^+, Gran alkalinity (or acid neutralization capacity, ANC), the sum of seasalt corrected base cations (Ca, Na, K, Mg), colour, Cl^- and SO_4^{-2}.

RESULTS

We tested each data set for the null hypothesis of no significant trend at the 95% confidence level. The trend analysis results for the lakes in each cluster are reported in Table 3. Site specific trend analysis results, as well as statistical significance are listed in Appendix C. Figures showing the fluctuation in pH, ANC, C_b and SO_4^{-2} values at each site are shown in Appendix D.

Acidity

Acidity measured as pH or H^+ was remarkably stable in Nova Scotia, as only one lake from Cluster 1 and one in Cluster 3, both located in the western part of the Province showed decreasing pH, or increasing H^+ trends (Table 3). As both these sites are located close to the western coast of Nova Scotia and thus heavily influenced by seaspray, and as some of them are affected by human activity, these results may not indicate long-range acidification effects.

Almost half of all Newfoundland lakes showed pH increases, one showed a decrease and the remainder (17) showed no trend. H^+ trends were less clearcut, with four sites showing increasing values, eight showing decreasing trends, and 21 with no change. It seems that the normalization which occurs in the calculation of pH tends to smooth out the data and reduces background noise. It was also noted that pH and H^+ trends were not necessarily detected in the same lakes.

Three of the four sites showing acidity increases were small lakes in Cluster 1 sites located on granite mountains on the west coast of the Newfoundland. Little soil is found in these

basins, and the sites are heavily influenced by snowmelt or rain events. Nevertheless, the same pattern was noted for H^+ and pH ie., a reduction in water acidity is indicated in the Newfoundland lakes.

Though there was a difference between trends in N.S. and Newfoundland, there were no real differences in acidity trends within either Nova Scotia or Newfoundland. The magnitude of the acidity decrease ranged from 0.58 to 0.03 μeq year^{-1}. The increases observed on the west coast of Newfoundland ranged from 1.1 to 0.14 μeq year^{-1}. The overall conclusion that can be made from these data is that water acidity as measured by pH did not change in Nova Scotia during the period of record, but that Newfoundland lake pH increased significantly.

Acid neutralization capacity

In Nova Scotia, 13 of the 42 lakes showed increasing ANC (with none showing decreases). ANC in six Newfoundland lakes increased, with none decreasing. There were no obvious differences in trends among clusters in either region, as three of five Nova Scotia and four of five Newfoundland clusters showed lakes with increasing trends.

Table 3. Summary of parameter trends from each cluster in Nova Scotia and Newfoundland. Up arrows denote increases in values; down arrows, decreases; and left-right arrows, no trends.

	Nova Scotia			Newfoundland		
	↑	↓	↔	↑	↓	↔
Clust.1						
pH	0	0	11	3	1	7
H^+	0	1	10	4	2	5
ANC	8	0	3	1	0	10
C_b	1	0	10	1	1	9
SO_4^{-2}	2	2	7	0	3	8
Clust.2						
pH	0	0	5	2	0	0
H^+	0	0	5	0	0	2
ANC	2	0	3	2	0	0
C_b	0	0	5	0	0	2
SO_4^{-2}	0	0	5	0	0	2
Clust.3						
pH	0	1	12	4	0	8
H^+	0	0	13	0	3	9
ANC	0	0	13	2	0	10
C_b	0	1	12	1	2	9
SO_4^{-2}	0	0	13	2	1	9
Clust.4						
pH	0	0	6	4	0	1
H^+	1	0	5	0	3	2
ANC	3	0	3	0	0	5
C_b	0	1	5	0	0	5
SO_4^{-2}	0	3	3	0	0	5
Clust.5						
pH	0	0	4	2	0	1
H^+	0	0	4	0	0	3
ANC	0	0	4	1	0	2
C_b	0	0	4	0	0	3
SO_4^{-2}	0	0	4	0	0	3

The range in ANC increases in N.S. varied from 0.7 from site 01NS01ED0029 located at the Kejimkujik National Park, to 4.4 $\mu eq*L^{-1}year^{-1}$ at station 01NS01EA0011, found at the western tip of the province. In Newfoundland, trends ranged from 1.1 at station 01NF02ZC0003 located on the south coast, to 3.2 $\mu eq*L^{-1}year^{-1}$ at lake 01NF02YS0009, located at Terra Nova National Park. The number of lakes with increasing ANC supports the fact that the lakes seem to be responding to the lower deposition rates measured.

Based on Equation 1, there are two possibilities for the increase in ANC. The first is that there be a decrease in ΣC_a from decreases in SO_4^{-2} precipitation, and the second, that there be an increase in ΣC_b. Analysis of these two components was also done.

Sum of Base Cations C_b

In Nova Scotia, C_b increased in only one lake, as opposed to two where it decreased. In Newfoundland, two increased while three decreased. Overall, the low number of lakes which showed any trend, either up or down suggests that this parameter is very stable, perhaps because changes in base cations if they occur, are too subtle to allow succesful trend detection. As C_b is composed of calcium, potassium, magnesium and sodium, all seasalt corrected and all measured separately, the variability inherent in multiple analyses tend to dampen any potential trends.

Sulfate

Sulfate concentrations remained unchanged in all Nova Scotian clusters, except Cluster 4 (high base cations, moderate organic anions), where it decreased at four sites. As all Nova Scotia Cluster 4 sites are located in the extreme western part of the area, on confused geology and are strongly impacted by seaspray from the nearby ocean (Howell 1986), the trends measured could be due to factors unrelated to acid precipitation. The high base cation content at some of the sites (Clair and Esterby 1991) also suggests that evaporites, such as gypsum ($CaSO_4$) or anhydride ($CaSO_4*nH_2O$) in glacial till, or highway salting activities could be modifying SO_4^{-2} in water without affecting pH or ANC.

The Newfoundland situation is more confused. Sulfate decreased at three Cluster 1 sites (low cations, low organics), and gave mixed results in Cluster 3. Overall, it increased at two sites, decreased at three, and remained unchanged at 27 (Table 4). Confused geology (Ehrman and Clair ms) probably explains the inconsistent trends. The SO_4^{-2} results from neither region of the study area explain the improvement in pH and ANC which was measured in the lakes studied.

Colour

Only two sites in N.S., and five in Newfoundland showed colour increases while three Newfoundland sites showed decreases (Tables 3,4). These results imply that there were no consistent changes in the organic content of water from the sites over the study period, and that pH and ANC changes detected were probably not due to changes in organic acid effects. It also suggests that hydrologic conditions, which control water organic content in the regions (Clair and Freedman 1986) did not vary greatly during the study period.

DISCUSSION

Some seasonality was expected in the data because of the impact of chemical and biological processes which influence water chemistry over the course of the year. It was rarely discerned by the statistical tests for two reasons however. First, the data were highly influenced by year to year fluctuations on water chemistry probably caused by climatic variations. Twice yearly sampling probably was not suitable to provide adequate data to overcome this problem. Secondly, the lack of measured seasonality was also perhaps due to the shortness of the data set which did not allow natural longterm yearly variations to be expressed. The same was true for the results from the persistence analysis.

The length and sampling frequency of the data set are obviously important considerations in determining whether trends in chemistry could be measured. For a number of reasons, dictated by logistics, sampling of the lakes was only conducted twice yearly, which has been shown elsewhere to be useful in trend detection (Taylor and Loftis 1989). This was also confirmed by our work, as a number of variable trends could be detected at a 95% confidence level. The data sets which showed no seasonality, but did show persistence, were analyzed using the Spearman/Lettenmaier test and never showed trends, even though data collected at nearby sites and analyzed using one of the Kendall methods often did. The reason for the lack of trends using the S/L technique is that this test is low powered and required at least 20 data points for use in method application (Berryman et al. 1988). Usually, only 12 or 13 data points were available. Use of other methods on this data, especially the Kendall seasonal test might have resulted in a greater number of detectable trends, but we felt that a a more rigorous application

of method conditions was necessary to provide a conservative approach to data interpretation.

As there seemed to be consistent types of trends within each of the two regions regardless of cluster grouping, it was thought useful to sum the trends from all sites in each province to see if overall conclusions could be made about large scale changes in water chemistry (Table 4). Based on the electroneutrality principle (Equation 1), it was expected that as SO_4^{-2} decreased somewhat in Nova Scotia, ANC would increase. This was often the case, though the ANC trend was much more evident than that of SO_4^{-2}.

Another parameter which could hold a clue to the lack of confirmation of trends is NO_3^-. Though not reported on here, it was consistently measured. Nitrate values were usually below the 0.01 $mg*L^{-1}$ analytical detection limit in both Nova Scotia and Newfoundland freshwaters. Despite not being measurable because of biological uptake in the basins, they are deposited at low levels in the region (RMCC 1990b) and are quite likely involved in controlling both pH and ANC levels. Future work should attempt to clarify the function of NO_3^- in modifying basin water chemistry.

Table 4. Summary of trends in sampling lakes of the Atlantic region.

	Nova Scotia			Newfoundland		
	↑	↓	↔	↑	↓	↔
SO_4^{-2}	2	6	32	2	3	27
pH	0	1	39	15	1	16
ANC	13	0	27	6	0	26
C_b^*	1	2	37	2	3	27
Colour	2	0	38	5	3	24
Cl	0	3	26	6	0	19

By studying all the individual lakes in the data set, we can see that 29 showed either increases in pH or ANC or a decrease in SO_4^{-2}, which we consider to be improvements in lake quality. One lake showed a pH decrease, and 42 showed either no, or offsetting conflicting trends.

Not surprisingly, Cluster 1, containing the lakes with the most dilute chemistryand thus the most sensitive to atmospheric inputs, had the highest proportion of sites with detectable trends though these were not always consistent (Table 3). For example, 2 of 11 lakes in Nova Scotia showed increasing SO_4^{-2} trends, 2 decreasing and the remainder, none. In Newfoundland, SO_4^{-2} at 3 sites decreased, while no lakes showed increases.

Results from Atlantic Canada were compared to those of Bouchard and Haemmerli (1990) who, using identical statistical approaches, measured trends in SO_4^{-2}, pH and ANC from Québec lakes from 1983 to 1988. Their results partly conflict with ours, as they detected increases in SO_4^{-2} and acidity and decreases in ANC in the southcentral part of the province, the area closest to Newfoundland. The difference between results may be due to local sources in the region, to

differences in weather patterns, or to a combination of the two.

Our lake results differed from trends in river chemistry measured by Clair and Whitfield (1983). Using Box-Jenkins trend analysis, they showed pH decreases in sensitive rivers of the region from 1966-69 to the mid and late 1970's. They also were unable to show corresponding changes in other ions. More recently, Lettenmaier et al. (1991) also showed that pH and alkalinity increased in a number of American rivers, suggesting reduced acidification effects.

Our inability to show corroborative changes in other parameters is an indication of the complex series of chemical reactions and basin integrative processes which occur in soils, snow and waters, such as seasonal storage and preferential release of ions. Moreover, changes in organic acidity which are controlled by land-use and hydrological factors are perhaps also partly responsible for the lack of complete correlation between related parameters.

To summarize, we show that a number of lake water chemistry parameters which have been related to anthropogenic acidification have improved between 1983 and 1989 in a number of lakes from Nova Scotia and Newfoundland. These improvements have occurred simultaneously with decreases in SO_4^{-2} deposition in the region. These results tend to confirm the findings of the water chemistry models produced for this area (Bobba and Lam 1990).

Though the trends in individual lakes for pH, ANC and SO_4^{-2} do not necessarily confirm each other, neither do they contradict themselves. Our data indicate that a general improvement in acidification related water chemistry has occurred in the lakes of the monitoring network and that the improvement occurred over the breadth of the 1200 km wide sampling area.

ACKNOWLEDGEMENTS

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APPENDIX A

NAQUADAT number, name, Cluster group, Map area (from Fig. 1) and location of Nova Scotia lake sites in the monitoring network.

Station #	Lake name	Clus. #	Map Area	Lat. ° ' "	Long. ° ' "
01NS01DA0002	Tedford	2	A	44 06 00	66 01 00
DA0003	Killams	2	A	44 00 03	66 04 57
DA0004	Cedar	4	A	44 01 36	66 06 39
DA0005	Cornings	2	A	44 03 00	66 05 00
DA0006	Pierce	2	A	44 07 10	66 05 50
DA0007	Coggins	4	A	43 58 42	66 06 30
EA0002	George	1	A	44 00 00	66 04 00
EA0004	Jesse	1	A	44 01 59	66 00 29
EA0009	Brenton	5	A	43 57 41	66 04 09
EA0010	Trefrey	4	A	43 50 07	66 02 38
EA0011	Allens	4	A	43 56 47	66 09 11
EA0014	Churchill	4	A	43 59 26	66 08 21
EA0016	Darlings	4	A	43 58 05	66 07 17
EA0019	Snare	3	A	44 06 20	65 58 32
EA0020	Bird	2	A	43 58 23	65 56 39
EB0007	Caesar	4	A	43 33	65 31
ED0001	Back	1	B	44 17 30	65 16 00
ED0002	Big Dam West	3	B	44 27 30	65 17 30
ED0003	Big Dam East	1	B	44 27 00	65 16 00
ED0004	Mountain	1	B	44 19 30	65 16 00
ED0005	Peskowesk	1	B	44 19 00	65 17 00
ED0006	Grafton	2	B	44 23 00	65 10 00
ED0007	Kejimkujik	3	B	44 22 00	65 13 30

ED0008	High	3	B	44 21 30	65 15 30
ED0010	Pebbleloggitch	3	B	44 19 00	65 21 00
ED0011	Cobrielle	1	B	44 19 00	65 14 00
ED0013	Ben	1	B	44 20 30	65 20 00
ED0014	Big Red	5	B	44 21 00	65 23 00
ED0015	Mud	3	B	44 21 30	65 13 30
ED0016	Snake	5	B	44 21 30	65 12 30
ED0017	Liberty	1	B	44 23 00	65 25 30
ED0019	Frozen Ocean	3	B	44 27 00	65 21 00
ED0020	Channel	3	B	44 25 00	65 18 30
ED0021	Little Red	5	B	44 20 21	65 23 45
ED0022	Poplar	1	B	44 21 30	65 26 30
ED0025	Luxton	3	B	44 21 30	65 20 30
ED0027	Beaverskin	1	B	44 18 30	65 20 00
ED0028	McGinty	3	B	44 21 30	65 09 30
ED0029	Peskawa	3	B	44 19 00	65 22 00
ED0030	Upper Silver	1	B	44 17 00	65 15 00
ED0043	Mount Tom	3	B	44 22 05	65 18 00
ED0047	George	3	B	44 20 25	65 13 15
ED0048	Loon	3	B	44 19 00	65 11 00

APPENDIX B

NAQUADAT number, name, Cluster group, Map area (from Fig. 2) and location of Newfoundland lake sites in the monitoring network.

Station #	Lake name	Clus. #	Map Area	Lat.	Long.
				° ' "	° ' "
SITES					
01NF02YD0007	unnamed	3	F	50 43 14	56 25 05
YH0011	unnamed	1	F	49 33 40	57 43 25
YH0012	unnamed	1	F	49 31 24	57 42 39
YH0013	unnamed	1	F	49 35 48	57 44 00
YH0014	unnamed	1	F	49 26 14	57 31 54
YH0015	unnamed	1	F	49 27 39	57 31 30
YK0006	unnamed	4	F	48 47 45	57 39 37
YL0001	unnamed	4	F	49 24 28	57 13 18
YL0010	unnamed	1	F	49 30 00	57 32 44
YM0001	Noble Pond	1	J	49 49 05	55 54 51
YM0003	unnamed	3	J	49 32 29	56 38 16
YM0006	unnamed	3	J	49 44 29	56 10 01
YM0007	unnamed	5	J	49 50 39	56 05 44
YN0008	Sandy	4	J	48 49 04	56 56 43
YO0009	Tally Pond	2	J	48 36 34	56 29 27
YQ0001	Bellman's Pd	4	J	49 10 46	54 39 07
YQ0020	Headwater	4	J	48 16 00	55 28 59
YQ0021	Spruce Pond	4	J	48 19 00	55 28 00
YR0005	unnamed	3	J	49 12 05	54 08 00
YS0003	Rattle Pond	3	G	48 30 50	53 49 28
YS0005	Shallow Pd #3	3	G	48 30 15	53 49 30
YS0009	Ochre Hill Pd	3	G	48 30 10	53 57 50
YS0010	Chatman Pd W.	5	G	48 29 39	53 59 03

YS0016	unnamed #2	4	G	48 33 00	53 51 00
YS0021	Bog Pond	4	G	48 29 39	54 07 59
YS0029	Long Waters	3	G	48 27 29	54 03 20
YS0045	Jay Pond	5	G	48 38 12	53 53 03
YS0048	Moses Cove Pd	3	G	48 35 48	53 45 16
ZB0001	Big Pond	1	H	47 50 54	58 13 18
ZB0005	unnamed	1	H	47 49 00	58 55 59
ZB0007	unnamed	1	H	47 43 00	58 55 00
ZC0002	unnamed	1	H	47 48 06	57 18 43
ZC0003	Stephenson's	1	H	47 54 45	57 29 47
ZC0016	unnamed	1	H	48 00 00	57 45 00
ZC0017	unnamed	1	H	47 46 59	57 46 59
ZD0001	unnamed	1	H	47 48 39	56 34 54
ZD0002	unnamed	3	H	48 04 31	56 41 33
ZD0006	unnamed	3	H	47 47 30	56 34 28
ZF0003	unnamed	1	H	47 50 03	54 49 13
ZF0004	Hungry Grove	2	H	47 50 42	55 07 00

APPENDIX C

Detailed lake trend results for each parameter analyzed in both parts of the study area. KEND. denotes the use of the straight Kendall test, K.S. is the Kendall Seasonal and S/L is the Spearman Lettenmaier test. There were no sites which demonstrated both persistence and seasonality, and thus no Hirsh and Slack results.

Table C1. pH trend statistics for stations with Cluster 1 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0002	NO	NO	KEND.	0.05	N/A
EA0004	NO	NO	KEND.	0.09	N/A
ED0001	NO	NO	KEND.	0.24	N/A
ED0003	NO	NO	KEND.	0.16	N/A
ED0004	NO	NO	KEND.	0.32	N/A
ED0005	YES	NO	K.S.	0.27	N/A
ED0011	NO	NO	S/L	N/A	N/A
ED0017	NO	NO	S/L	N/A	N/A
ED0022	NO	NO	S/L	N/A	N/A
ED0027	NO	NO	KEND.	0.42	N/A
ED0030	NO	NO	KEND.	0.42	N/A
Newfoundland					
01NF02YH0011	NO	↓	KEND.	0.04	0.03
YH0012	YES	NO	K.S.	0.11	N/A
YH0013	NO	NO	KEND.	0.41	N/A
YH0014	NO	NO	S/L	N/A	N/A
YH0015	NO	NO	KEND.	0.25	N/A
YL0010	NO	NO	S/L	N/A	N/A
YM0001	NO	NO	KEND.	0.12	N/A
ZC0002	NO	NO	S/L	N/A	N/A
ZC0003	NO	↑	KEND.	0.02	0.06
ZD0001	NO	↑	KEND.	0.02	0.05
ZF0003	NO	↑	KEND.	0.02	0.05

Units are pH/year

Table C2. pH trend statistics for stations with Cluster 2 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01DA0003	NO	NO	KEND.	0.09	N/A
DA0005	NO	NO	KEND.	0.21	N/A
DA0006	NO	NO	KEND.	0.40	N/A
EA0020	NO	NO	KEND.	0.20	N/A
ED0006	NO	NO	KEND.	0.12	N/A
Newfoundland					
01NF02YD0009	NO	↑	KEND.	0.5	0.05
ZF0004	NO	↑	S/L	N/A	0.08

Units are pH/year

Table C3. pH trend statistics for stations with Cluster 3 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0019	NO	↓	S/L	N/A	0.02
ED0002	NO	NO	KEND.	0.18	N/A
ED0007	YES	NO	S/L	N/A	N/A
ED0008	NO	NO	KEND.	0.08	N/A
ED0010	NO	NO	S/L	N/A	N/A
ED0015	NO	NO	KEND.	0.25	N/A
ED0019	NO	NO	KEND.	0.17	N/A
ED0020	NO	NO	KEND.	0.14	N/A
ED0025	NO	NO	KEND.	0.45	N/A
ED0028	NO	NO	KEND.	0.45	N/A
ED0029	NO	NO	KEND.	0.15	N/A
ED0047	NO	NO	S/L	N/A	N/A
ED0048	NO	NO	S/L	N/A	N/A
Newfoundland					
01NF02YM0003	NO	NO	KEND.	0.07	N/A
YM0006	NO	NO	KEND.	0.17	N/A
YO0007	NO	NO	KEND.	0.17	N/A
YR0005	NO	NO	KEND.	0.27	N/A
YS0003	NO	NO	KEND.	0.08	N/A
YS0005	NO	NO	KEND.	0.05	N/A
YS0009	NO	↑	KEND.	0.03	0.1
YS0021	NO	NO	KEND.	0.07	N/A
YS0029	NO	↑	KEND.	0.03	0.06
YS0048	NO	↑	S/L	N/A	0.06
ZB0006	NO	NO	KEND.	0.22	N/A
ZD0002	NO	↑	KEND.	0.04	0.05

Units are pH/year

Table C4. pH trend statistics for stations with Cluster 4 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01DA0004	NO	NO	KEND.	0.28	N/A
DA0007	NO	NO	KEND.	0.38	N/A
EA0010	NO	NO	KEND.	0.38	N/A
EA0011	NO	NO	KEND.	0.44	N/A
EA0014	NO	NO	KEND.	0.37	N/A
EA0016	NO	NO	KEND.	0.20	N/A
Newfoundland					
01NF02YK0006	NO	↑	KEND.	0.03	0.07
YN0008	NO	↑	KEND.	0.01	0.08
YQ0001	NO	↑	KEND.	0.03	0.06
YS0016	NO	↑	KEND.	0.01	0.09
YL0001	NO	NO	KEND.	0.12	N/A

Units are pH/year

Table C5. pH trend statistics for stations with Cluster 5 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0009	NO	NO	KEND.	0.37	N/A
ED0014	NO	NO	KEND.	0.33	N/A
ED0016	NO	NO	S/L	N/A	N/A
ED0021	NO	NO	YES	0.36	N/A
Newfoundland					
01NF02YS0010	NO	↑	KEND.	0.05	0.08
YS0045	NO	↑	KEND.	0.05	0.11
YM0007	NO	NO	KEND.	0.15	N/A

Units are pH/year

Table C6. ANC trend statistics for stations with Cluster 1 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0002	NO	↑	KEND.	0.01	1.3
EA0004	YES	↑	K.S.	0.04	1.9
ED0001	NO	↑	KEND.	0.03	1.2
ED0003	NO	↑	KEND.	0.01	0.8
ED0004	NO	NO	KEND.	0.47	N/A
ED0005	YES	↑	K.S.	N/A	1.0
ED0011	NO	NO	KEND.	0.12	N/A
ED0017	NO	NO	KEND.	0.09	N/A
ED0022	NO	↑	KEND.	0.03	1.6
ED0027	NO	↑	KEND.	0.03	0.9
ED0030	NO	↑	KEND.	0.03	1.0
Newfoundland					
01NF02YH0011	NO	NO	KEND.	0.26	N/A
YH0012	NO	NO	KEND.	0.30	N/A
YH0013	NO	NO	KEND.	0.16	N/A
YH0014	NO	NO	KEND.	0.26	N/A
YH0015	NO	NO	KEND.	0.15	N/A
YL0010	NO	NO	KEND.	0.23	N/A
YM0001	NO	NO	KEND.	0.42	N/A
ZC0002	NO	NO	KEND.	0.05	N/A
ZC0003	NO	↑	KEND.	0.03	1.1
ZD0001	NO	NO	KEND.	0.08	N/A
ZE0003	YES	NO	S/L	N/A	N/A

Units are in μeq/L/year

Table C7. ANC trend statistics for stations with Cluster 2 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01DA0003	NO	↑	KEND.	0.002	1.8
DA0005	NO	↑	KEND.	0.001	2.9
DA0006	NO	NO	KEND.	0.24	N/A
EA0020	YES	NO	K.S.	0.11	N/A
ED0006	NO	NO	KEND.	0.35	N/A
Newfoundland					
01NF02YD0009	NO	↑	KEND.	0.05	1.6
ZF0004	NO	↑	KEND.	0.01	2.0

Units are in μeq/L/year

Table C8. ANC trend statistics for stations with Cluster 3 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope[a]
01NS01EA0019	NO	NO	KEND.	0.41	N/A
ED0002	NO	NO	S/L	N/A	N/A
ED0007	NO	NO	S/L	N/A	N/A
ED0008	NO	NO	KEND.	0.08	N/A
ED0010	NO	NO	S/L	N/A	N/A
ED0015	NO	NO	KEND.	0.37	N/A
ED0019	NO	NO	KEND.	0.37	N/A
ED0020	NO	NO	S/L	N/A	N/A
ED0025	NO	NO	KEND.	0.17	N/A
ED0028	YES	NO	S/L	N/A	N/A
ED0029	NO	NO	KEND.	0.07	N/A
ED0047	NO	NO	KEND.	0.20	N/A
ED0048	YES	NO	S/L	N/A	N/A
Newfoundland					
01NF02YM0003	YES	NO	K.S.	0.45	N/A
YM0006	YES	NO	S/L	N/A	N/A
YO0007	YES	NO	S/L	N/A	N/A
YR0005	NO	NO	KEND.	0.47	N/A
YS0003	YES	NO	S/L	N/A	N/A
YS0005	NO	NO	KEND.	0.36	N/A
YS0009	NO	↑	KEND.	0.02	3.2
YS0021	YES	NO	K.S.	0.39	N/A
YS0029	NO	NO	KEND.	0.09	N/A
YS0048	NO	NO	KEND.	0.12	N/A
ZB0006	NO	NO	KEND.	0.06	N/A
ZD0002	NO	↑	S/L	N/A	1.8

[a] Units are in μeq/L/year.

Table C9. ANC trend statistics for stations with Cluster 4 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01DA0004	YES	↑	S/L	N/A	1.7
DA0007	YES	NO	K.S.	0.27	N/A
EA0010	YES	↑	S/L	N/A	1.7
EA0011	NO	↑	KEND.	0.02	4.4
EA0014	YES	NO	S/L	N/A	N/A
EA0016	YES	NO	S/L	N/A	N/A
Newfoundland					
01NF02YK0006	YES	NO	K.S.	0.22	N/A
YN0008	NO	NO	KEND.	0.29	N/A
YQ0001	YES	NO	KEND.	0.48	N/A
YS0016	NO	NO	KEND.	0.15	N/A
YL0001	YES	NO	S/L	N/A	N/A

Units are in μeq/L/year

Table C10. ANC trend statistics for stations with Cluster 5 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0009	YES	NO	K.S.	0.28	N/A
ED0014	NO	NO	KEND.	0.19	N/A
ED0016	NO	NO	S/L	N/A	N/A
ED0021	NO	NO	S/L	N/A	N/A
Newfoundland					
01NF02YS0010	YES	NO	K.S.	0.07	N/A
YS0045	YES	NO	K.S.	0.13	N/A
YM0007	NO	↑	KEND.	0.05	1.95

Units are in μeq/L/year.

Table C11. Base cation trend statistics for stations with Cluster 1 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0002	NO	NO	KEND.	0.31	N/A
EA0004	NO	↑	KEND.	0.02	N/A
ED0001	NO	NO	KEND.	0.40	N/A
ED0003	NO	NO	KEND.	0.50	N/A
ED0004	NO	NO	KEND.	0.23	N/A
ED0005	NO	NO	KEND.	0.27	N/A
ED0011	NO	NO	KEND.	0.14	N/A
ED0017	NO	NO	KEND.	0.31	N/A
ED0022	NO	NO	KEND.	0.31	N/A
ED0027	NO	NO	KEND.	0.20	N/A
ED0030	NO	NO	KEND.	0.45	N/A
Newfoundland					
01NF02YH0011	NO	NO	KEND.	0.39	N/A
YH0012	YES	NO	K.S.	0.18	N/A
YH0013	NO	NO	KEND.	0.21	N/A
YH0014	NO	NO	KEND.	0.27	N/A
YH0015	NO	NO	KEND.	0.16	N/A
YL0010	NO	NO	KEND.	0.46	N/A
YM0001	NO	NO	KEND.	0.45	N/A
ZC0002	NO	NO	KEND.	0.07	N/A
ZC0003	YES	NO	K.S.	0.39	N/A
ZD0001	NO	↑	S/L	N/A	3.4
ZE0003	NO	↓	S/L	N/A	3.0

Units are in μeq/L/year

Table C12. Base cation trend statistics for stations with Cluster 2 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope
01NS01DA0003	NO	NO	KEND.	0.21	N/A
DA0005	NO	NO	KEND.	0.14	N/A
DA0006	NO	NO	KEND.	0.40	N/A
EA0020	NO	NO	KEND.	0.50	N/A
ED0006	NO	NO	KEND.	0.40	N/A
Newfoundland					
01NF02YD0009	NO	NO	KEND.	0.09	N/A
ZF0004	YES	NO	K.S.	0.45	N/A

Table C13. Base cation trend statistics for stations with Cluster 3 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0019	YES	NO	S/L	N/A	N/A
ED0002	YES	NO	S/L	N/A	N/A
ED0007	NO	NO	KEND.	0.20	N/A
ED0008	YES	NO	S/L	N/A	N/A
ED0010	YES	NO	S/L	N/A	N/A
ED0015	NO	NO	KEND.	0.20	N/A
ED0019	YES	NO	K.S.	0.45	N/A
ED0020	YES	↓	S/L	N/A	1.1
ED0025	NO	NO	KEND.	0.31	N/A
ED0028	YES	NO	S/L	N/A	N/A
ED0029	NO	NO	KEND.	0.136	N/A
ED0047	NO	NO	KEND.	0.31	N/A
ED0048	NO	NO	KEND.	0.40	N/A
Newfoundland					
01NF02YM0003	NO	↑	KEND.	0.04	2.6
YM0006	NO	NO	KEND.	0.13	N/A
YO0007	NO	NO	S/L	N/A	N/A
YR0005	NO	NO	KEND.	0.36	N/A
YS0003	YES	NO	S/L	N/A	N/A
YS0005	NO	NO	KEND.	0.45	N/A
YS0009	YES	NO	S/L	N/A	N/A
YS0021	YES	↓	S/L	N/A	3.5
YS0029	YES	NO	K.S.	0.45	N/A
YS0048	NO	↓	KEND.	0.01	9.6
ZB0006	YES	NO	K.S.	0.43	N/A
ZD0002	YES	NO	S/L	N/A	N/A

Units are in μeq/L/year

Table C14. Base cation trend statistics for stations with Cluster 4 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope
01NS01DA0004	NO	NO	KEND.	0.36	N/A
DA0007	NO	NO	KEND.	0.40	N/A
EA0010	NO	NO	KEND.	0.27	N/A
EA0011	NO	NO	KEND.	0.40	N/A
EA0014	NO	↓	KEND.	0.02	N/A
EA0016	NO	NO	KEND.	0.45	N/A
Newfoundland					
01NF02YK0006	YES	NO	S/L	N/A	N/A
YN0008	YES	NO	K.S.	0.36	N/A
YQ0001	YES	NO	K.S.	0.14	N/A
YS0016	YES	NO	S/L	N/A	N/A
YL0001	YES	NO	S/L	N/A	N/A

Table C15. Base cation trend statistics for stations with Cluster 5 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope
01NS01EA0009	YES	NO	S/L	N/A	N/A
ED0014	YES	NO	S/L	N/A	N/A
ED0016	YES	NO	K.S.	0.40	N/A
ED0021	YES	NO	S/L	N/A	N/A
Newfoundland					
01NF02YS0010	YES	NO	S/L	N/A	N/A
YS0045	YES	NO	S/L	N/A	N/A
YM0007	NO	NO	KEND.	0.11	N/A

Table C16. SO_4^{-2} Trend statistics for stations with Cluster 1 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0002	NO	↓	KEND.	0.004	.12
EA0004	NO	↓	KEND.	0.01	.11
ED0001	NO	NO	KEND.	0.06	N/A
ED0003	NO	NO	KEND.	0.45	N/A
ED0004	YES	NO	K.S.	0.25	N/A
ED0005	NO	NO	KEND.	0.27	N/A
ED0011	YES	NO	S/L	N/A	N/A
ED0017	YES	NO	K.S.	0.47	N/A
ED0022	NO	NO	KEND.	0.12	N/A
ED0027	NO	↑	KEND.	0.04	.08
ED0030	NO	↑	KEND.	0.03	.05
Newfoundland					
01NF02YH0011	NO	↓	KEND.	.03	.08
YH0012	NO	NO	KEND.	.11	N/A
YH0013	NO	↓	KEND.	.02	.04
YH0014	NO	NO	KEND.	.33	N/A
YH0015	NO	NO	KEND.	.27	N/A
YL0010	NO	↓	KEND.	.03	.15
YM0001	NO	NO	KEND.	.41	N/A
ZC0002	YES	NO	K.S.	.21	N/A
ZC0003	YES	NO	K.S.	.07	N/A
ZD0001	YES	NO	K.S.	.11	N/A
ZE0003	NO	NO	KEND.	.14	N/A

Units are in μeq/L/year

Table C17. SO_4^{-2} trend statistics for stations with Cluster 2 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope
01NS01DA0003	NO	NO	KEND.	0.04	N/A
DA0005	NO	NO	KEND.	0.27	N/A
DA0006	NO	NO	KEND.	0.18	N/A
EA0020	NO	NO	KEND.	0.16	N/A
ED0006	NO	NO	KEND.	0.20	N/A
Newfoundland					
01NF02YD0009	NO	NO	KEND.	0.14	N/A
ZF0004	NO	NO	KEND.	0.31	N/A

Table C18. SO_4^{-2} trend statistics for stations with Cluster 3 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01EA0019	NO	NO	KEND.	0.31	N/A
ED0002	NO	NO	KEND.	0.16	N/A
ED0007	NO	NO	KEND.	0.08	N/A
ED0008	NO	NO	KEND.	0.14	N/A
ED0010	NO	NO	KEND.	0.27	N/A
ED0015	NO	NO	KEND.	0.10	N/A
ED0019	NO	NO	KEND.	0.40	N/A
ED0020	NO	NO	KEND.	0.27	N/A
ED0025	NO	NO	KEND.	0.31	N/A
ED0028	NO	NO	KEND.	0.18	N/A
ED0029	NO	NO	KEND.	0.33	N/A
ED0047	NO	NO	KEND.	0.08	N/A
ED0048	NO	NO	KEND.	0.29	N/A
Newfoundland					
01NF02YM0003	NO	NO	KEND.	0.06	N/A
YM0006	NO	NO	KEND.	0.19	N/A
YO0007	NO	NO	KEND.	0.12	N/A
YR0005	NO	NO	KEND.	0.21	N/A
YS0003	NO	NO	KEND.	0.14	N/A
YS0005	NO	NO	KEND.	0.17	N/A
YS0009	NO	↑	KEND.	0.001	0.09
YS0021	NO	NO	KEND.	0.22	N/A
YS0029	NO	↑	KEND.	0.03	0.12
YS0048	NO	↓	KEND.	0.03	0.12
ZB0006	NO	NO	KEND.	0.43	N/A
ZD0002	NO	NO	KEND.	0.48	N/A

Units are in ueq/L/year

Table C19. SO_4^{-2} trend statistics for stations with Cluster 4 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope#
01NS01DA0004	NO	↓	KEND.	0.003	0.13
DA0007	NO	NO	KEND.	0.13	N/A
EA0010	NO	NO	KEND.	0.20	N/A
EA0011	NO	↓	S/L	N/A	0.23
EA0014	YES	NO	S/L	N/A	N/A
EA0016	NO	↓	KEND.	0.03	0.17
Newfoundland					
01NF02YK0006	NO	NO	KEND.	0.07	N/A
YN0008	NO	NO	KEND.	0.14	N/A
YQ0001	NO	NO	KEND.	0.05	N/A
YS0016	NO	NO	KEND.	0.12	N/A
YL0001	NO	NO	KEND.	0.47	N/A

Units are in μeq/L/year

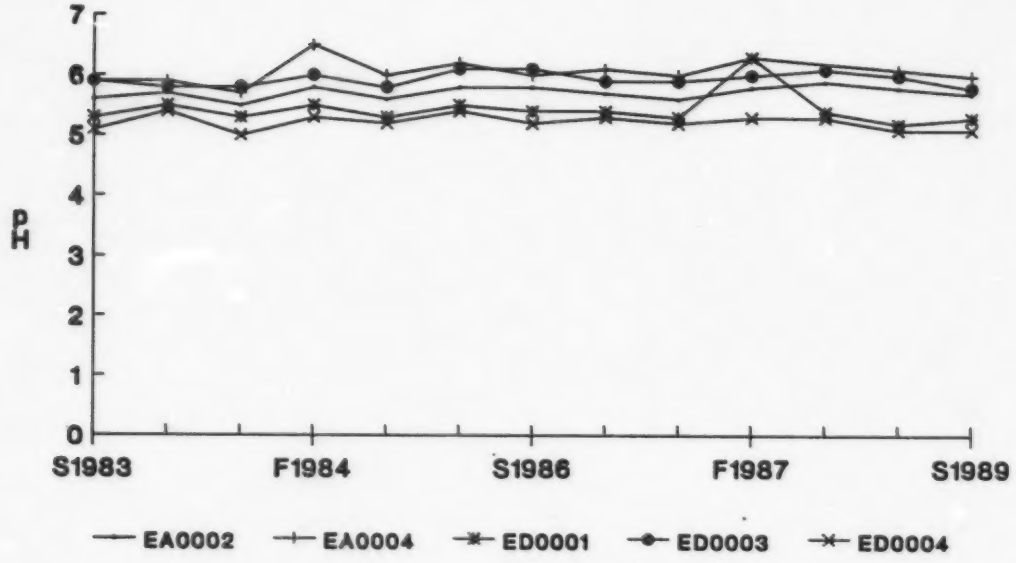
Table C20. SO_4^{-2} Trend statistics for stations with Cluster 5 characteristics in the Atlantic Canada lake acidification monitoring network.

Nova Scotia	seas.	Trend	Test	Sign.	Slope
01NS01EA0009	NO	NO	KEND.	0.16	N/A
ED0014	NO	NO	KEND.	0.23	N/A
ED0016	NO	NO	KEND.	0.09	N/A
ED0021	NO	NO	KEND.	0.2	N/A
Newfoundland					
01NF02YS0010	NO	NO	KEND.	0.27	N/A
YS0045	NO	NO	KEND.	0.21	N/A
YM0007	NO	NO	KEND.	0.42	N/A

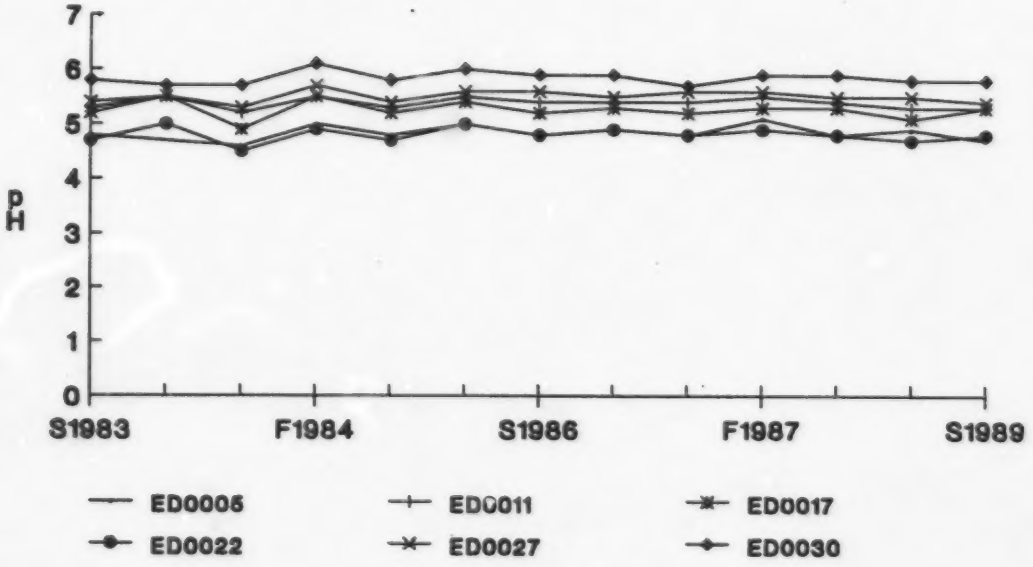
APPENDIX D

Graphical display of selected parameter values for each study lake within each cluster. Alk is the same as ANC, Ca, Mg, K are the sum of the base cations C_b^*, and $SSSO_4^{-2}$ is the seasalt corrected sulfate.

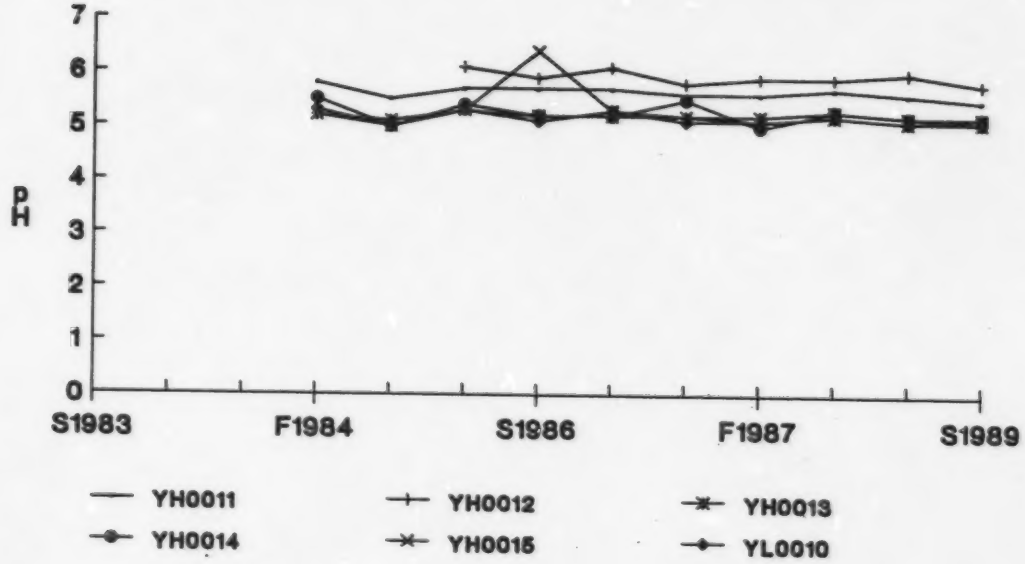
pH
CLUSTER 1A NOVA SCOTIA



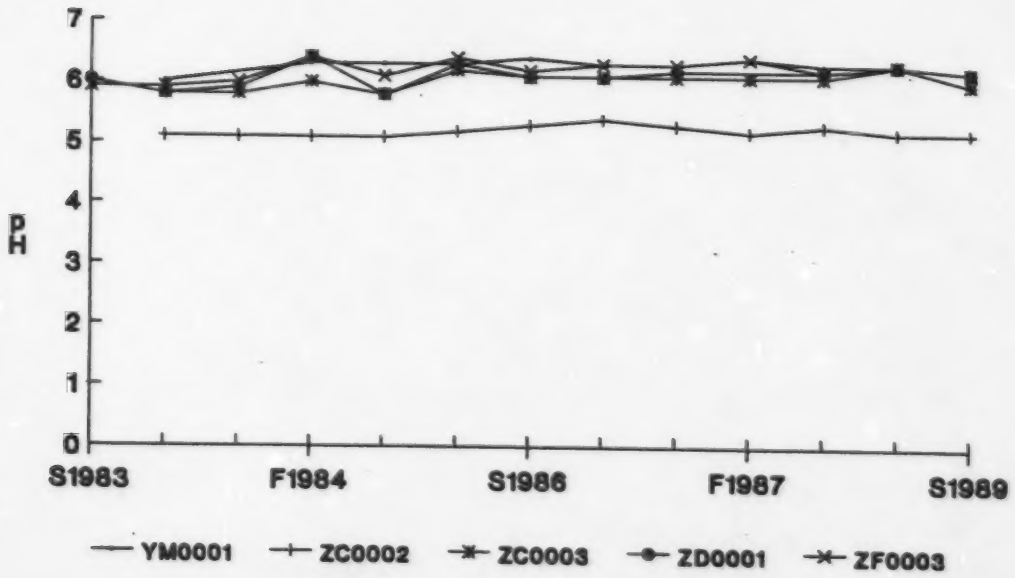
pH
CLUSTER 1B NOVA SCOTIA



pH
CLUSTER 1A NEWFOUNDLAND



pH
CLUSTER 1B NEWFOUNDLAND



pH
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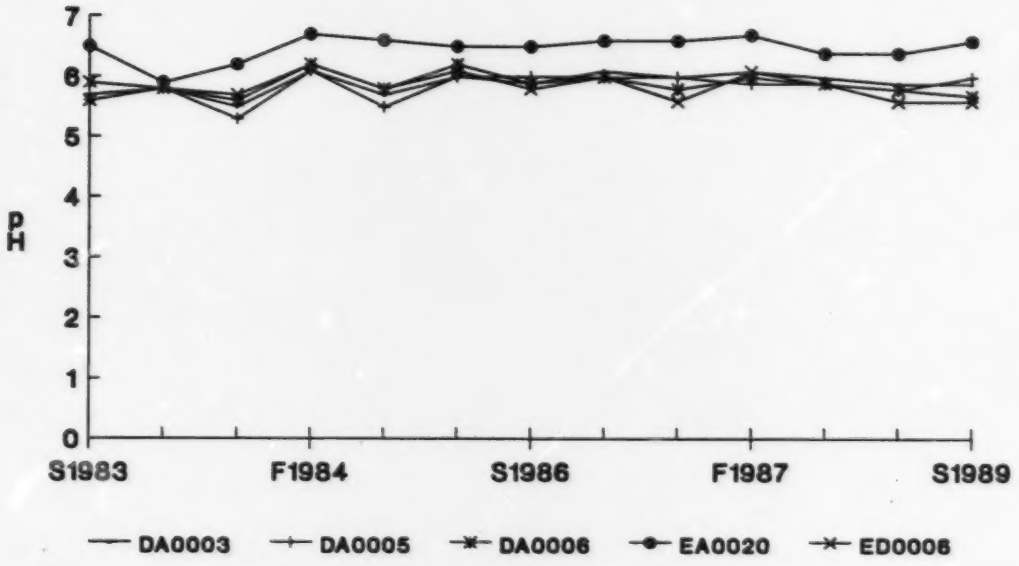
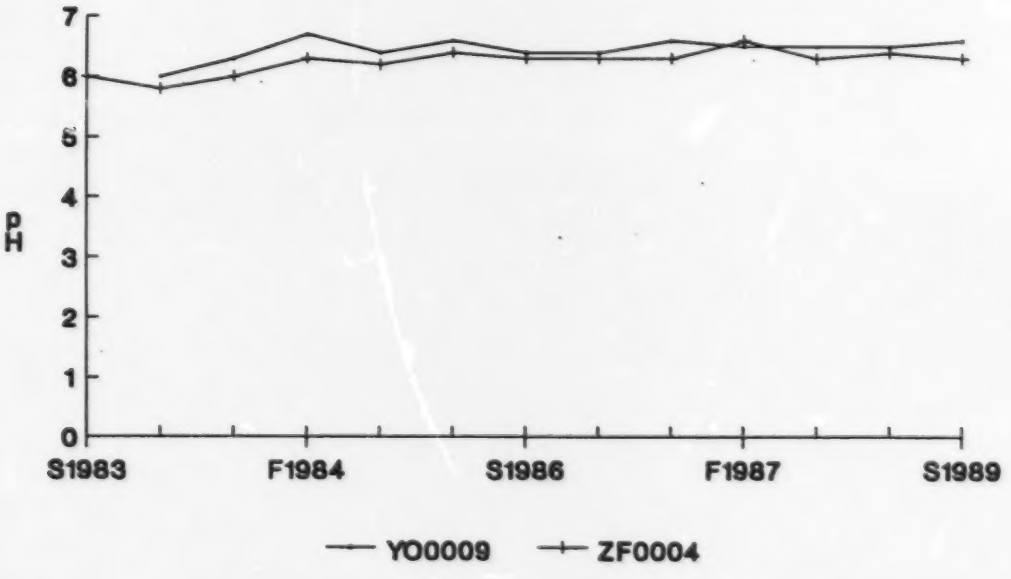
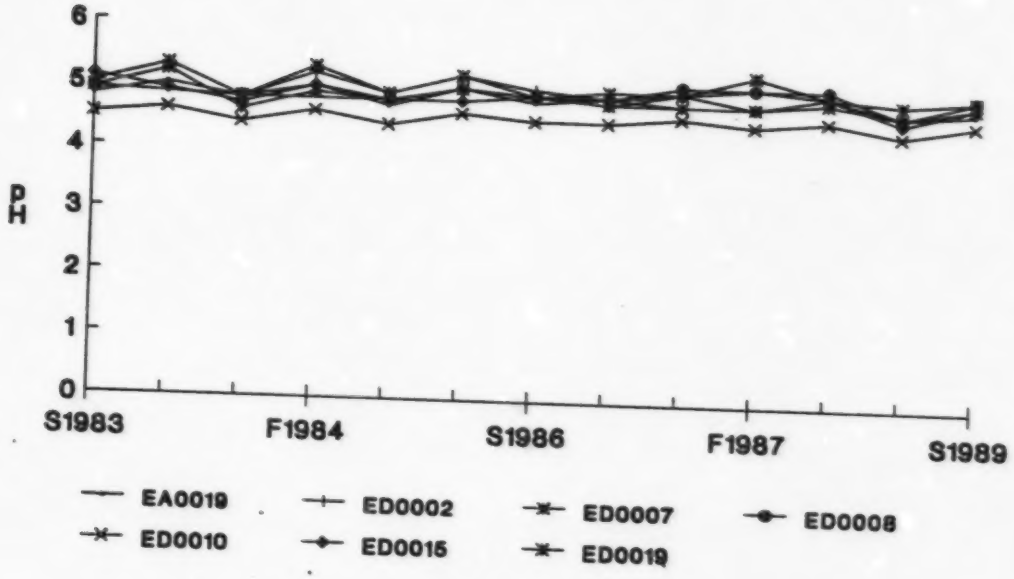


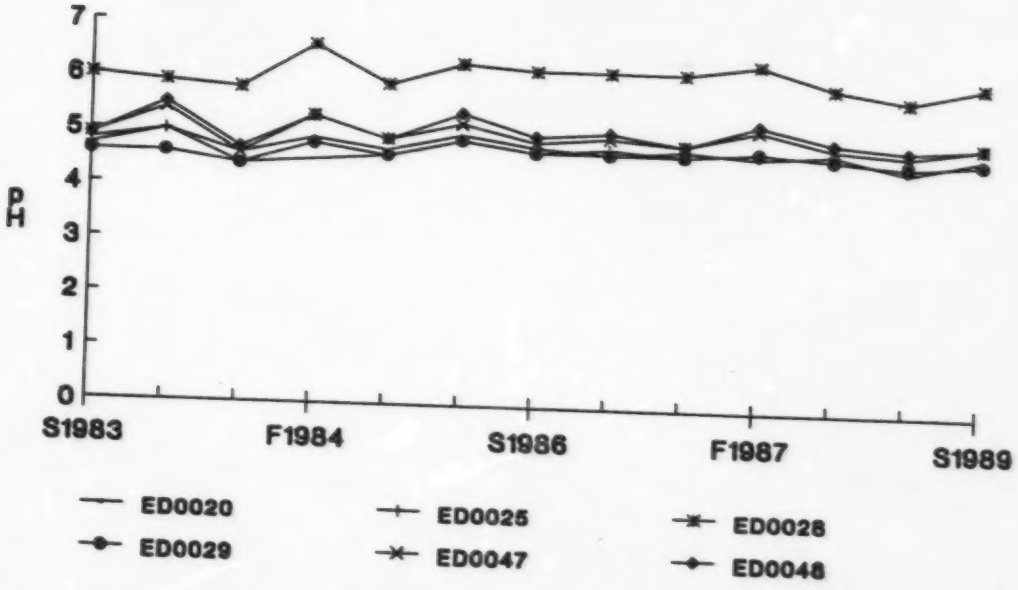
pH
CLUSTER 2 NEWFOUNDLAND



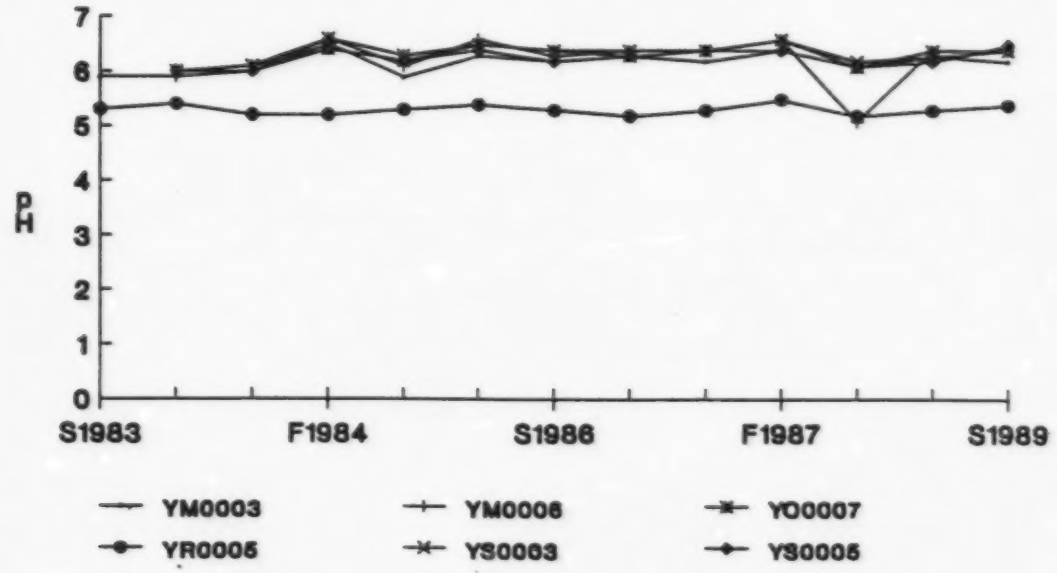
pH
CLUSTER 3A NOVA SCOTIA



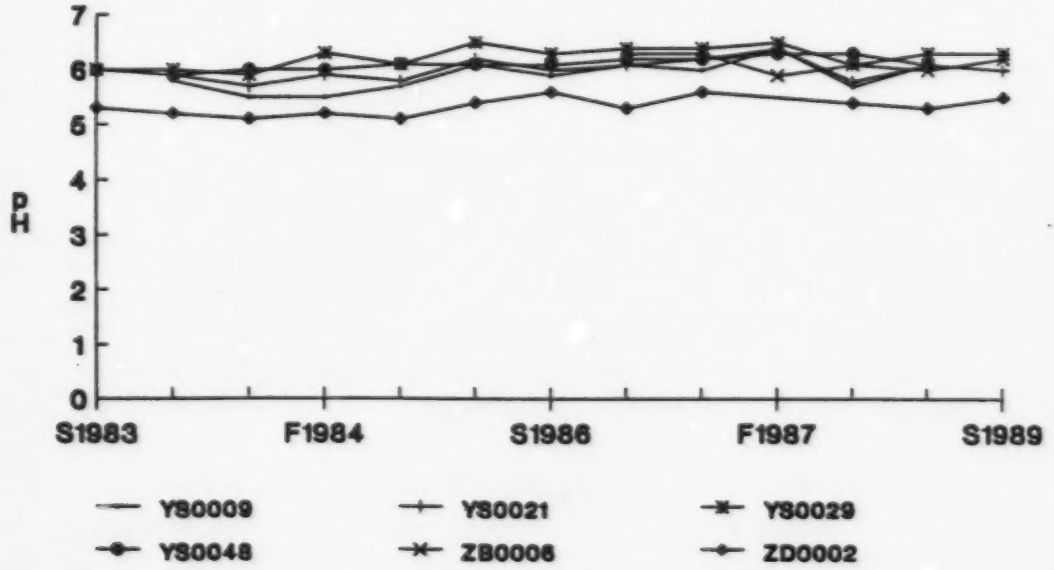
pH
CLUSTER 3B NOVA SCOTIA



pH
CLUSTER 3A NEWFOUNDLAND



pH
CLUSTER 3B NEWFOUNDLAND



pH
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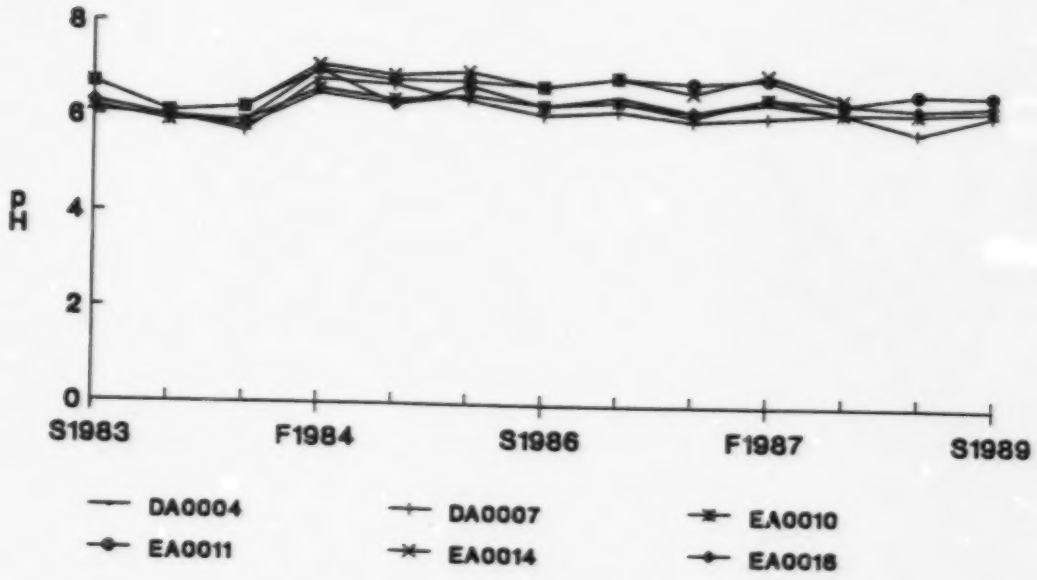
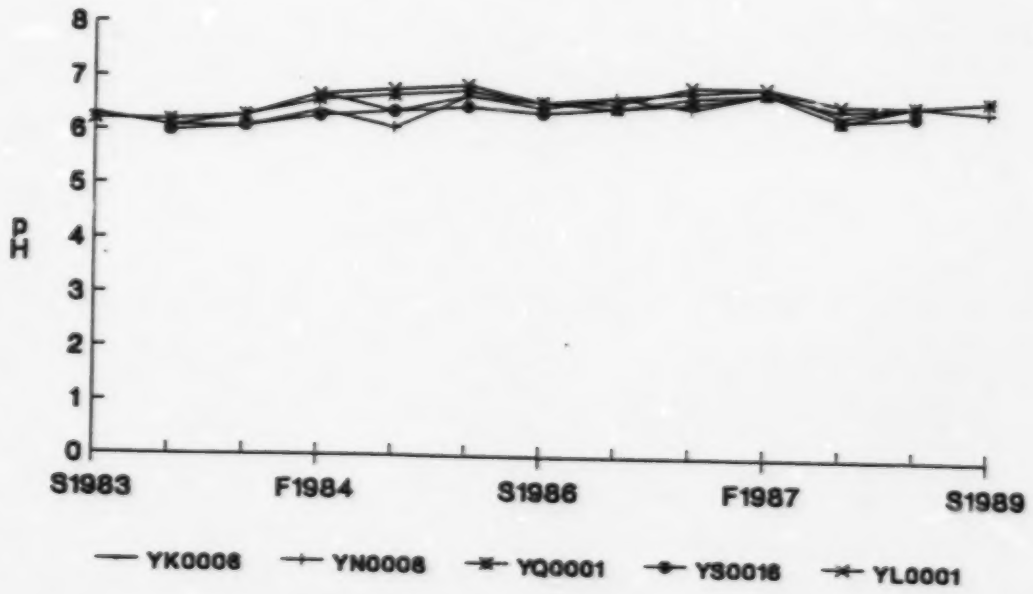


pH
CLUSTER 4 NEWFOUNDLAND



pH
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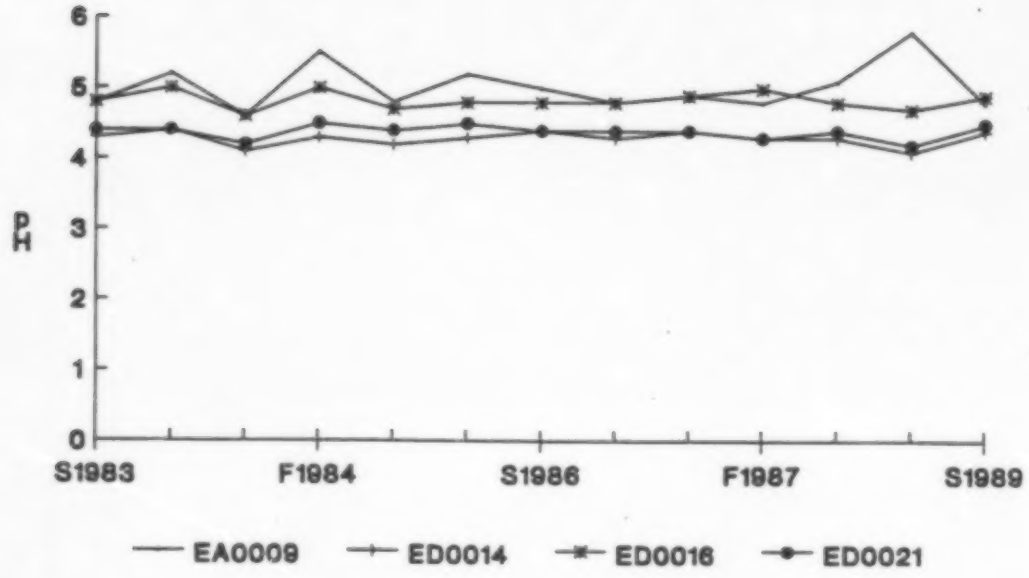
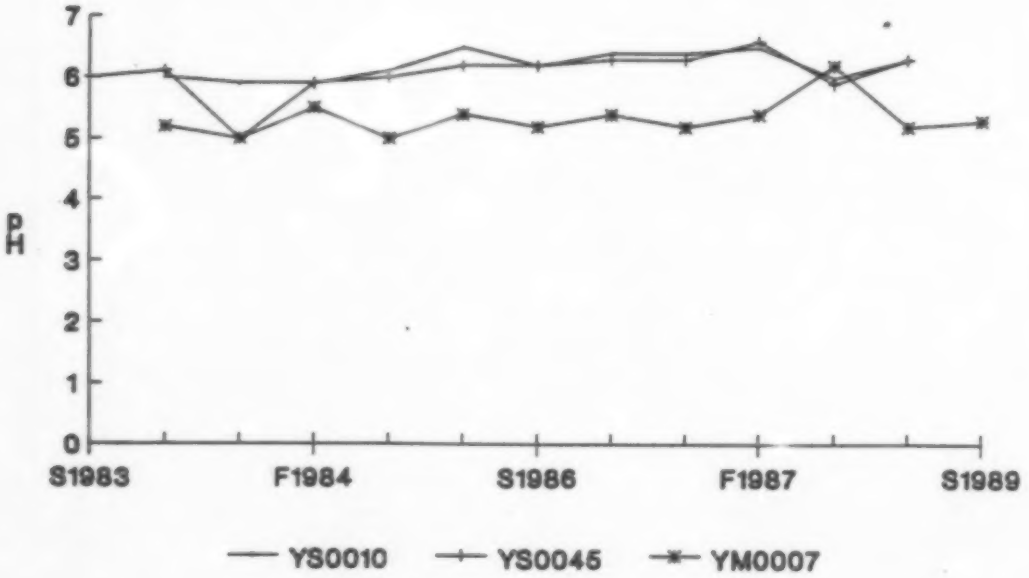
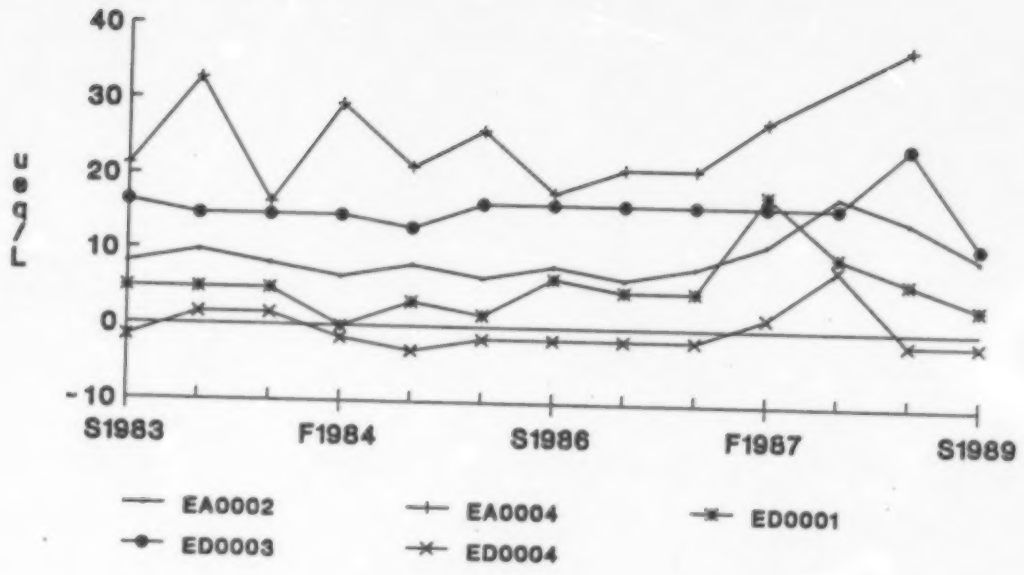


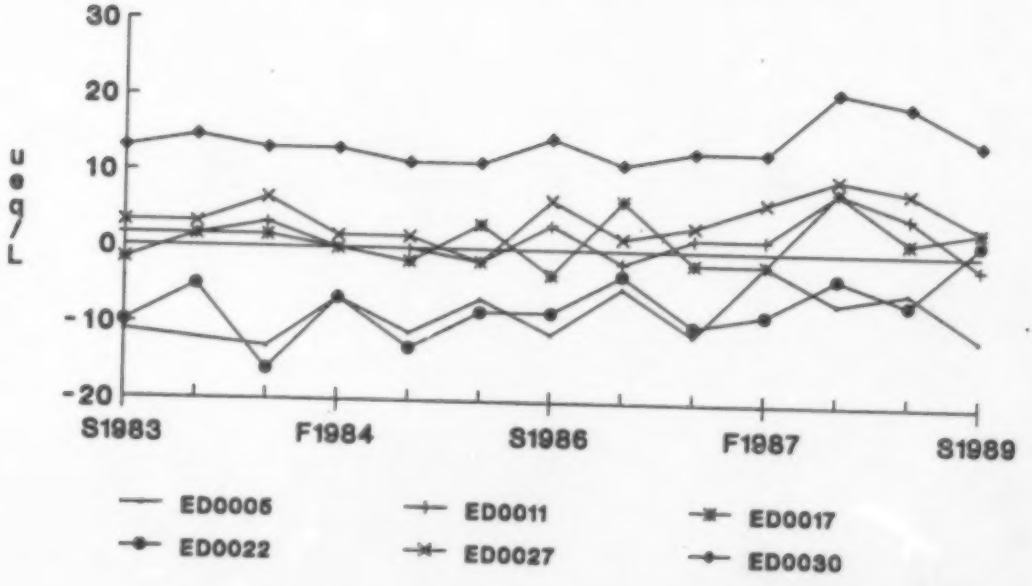
pH
CLUSTER 5 NEWFOUNDLAND



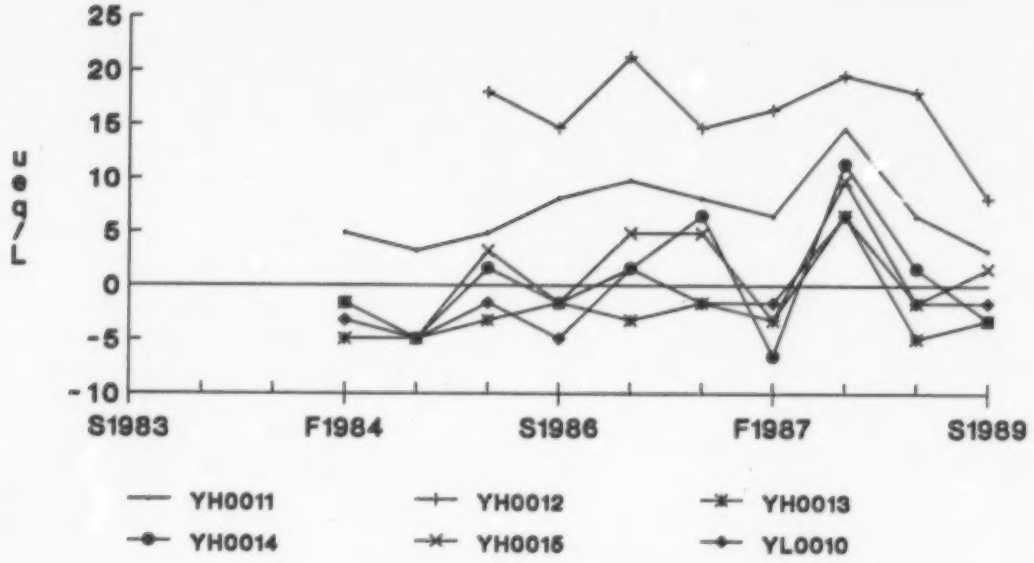
ALK
CLUSTER 1A NOVA SCOTIA



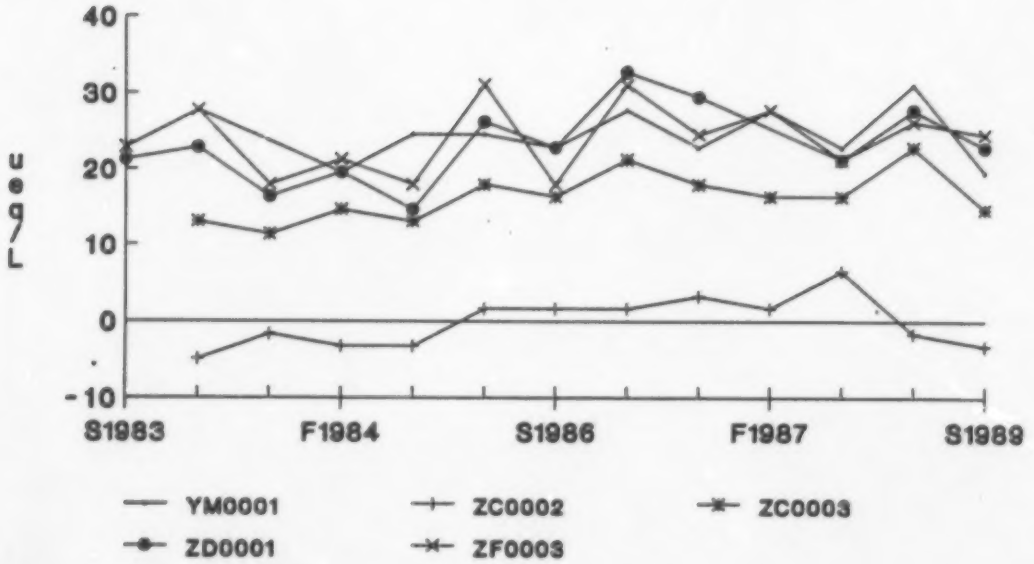
ALK
CLUSTER 1B NOVA SCOTIA



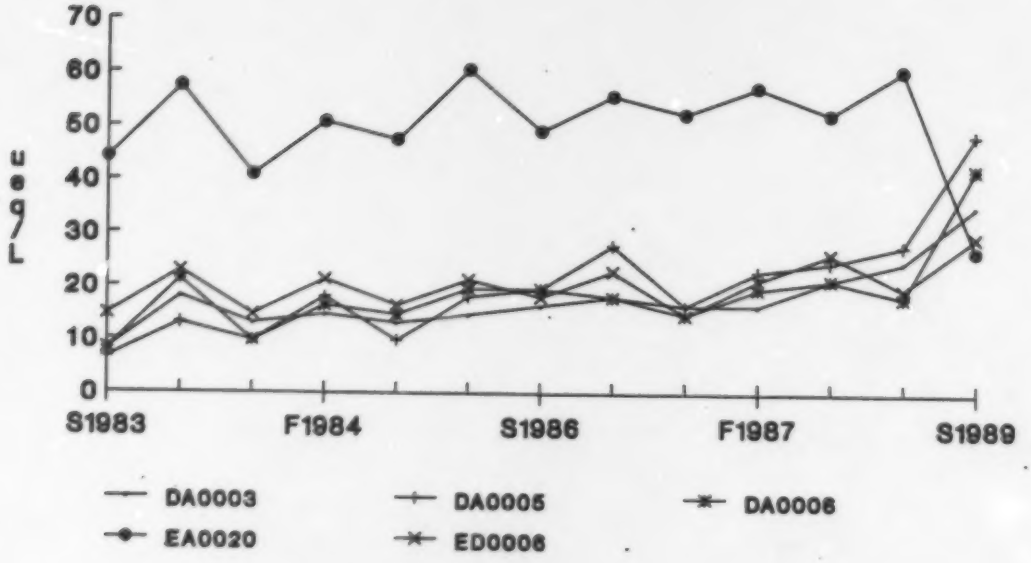
ALK
CLUSTER 1A NEWFOUNDLAND



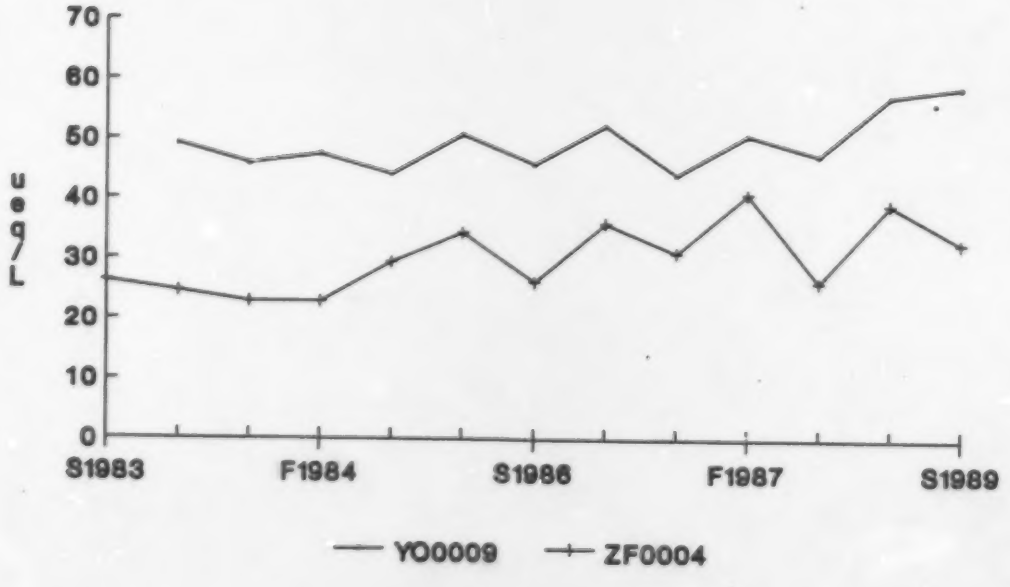
ALK
CLUSTER 1B NEWFOUNDLAND



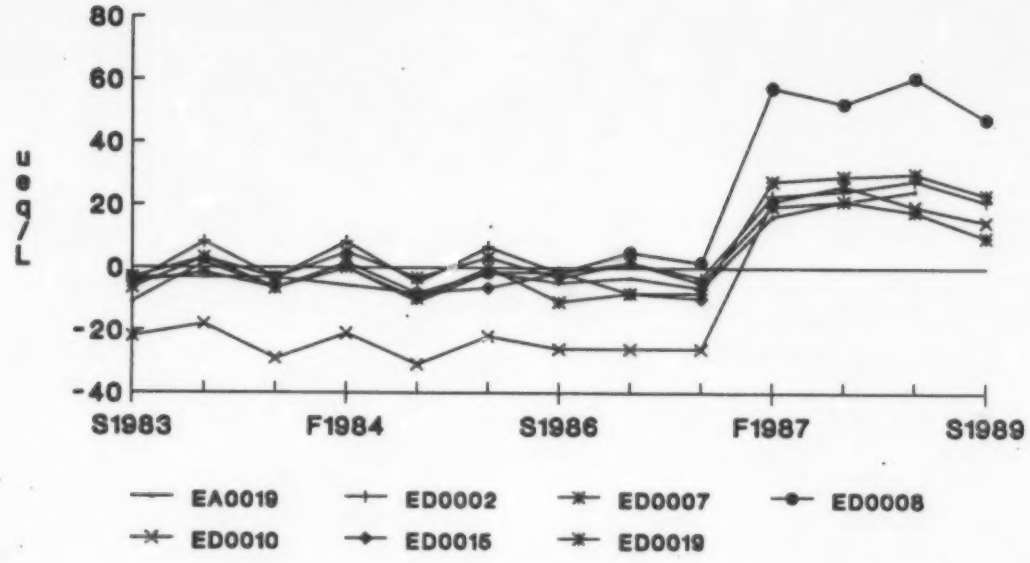
ALK
CLUSTER 2 NOVA SCOTIA



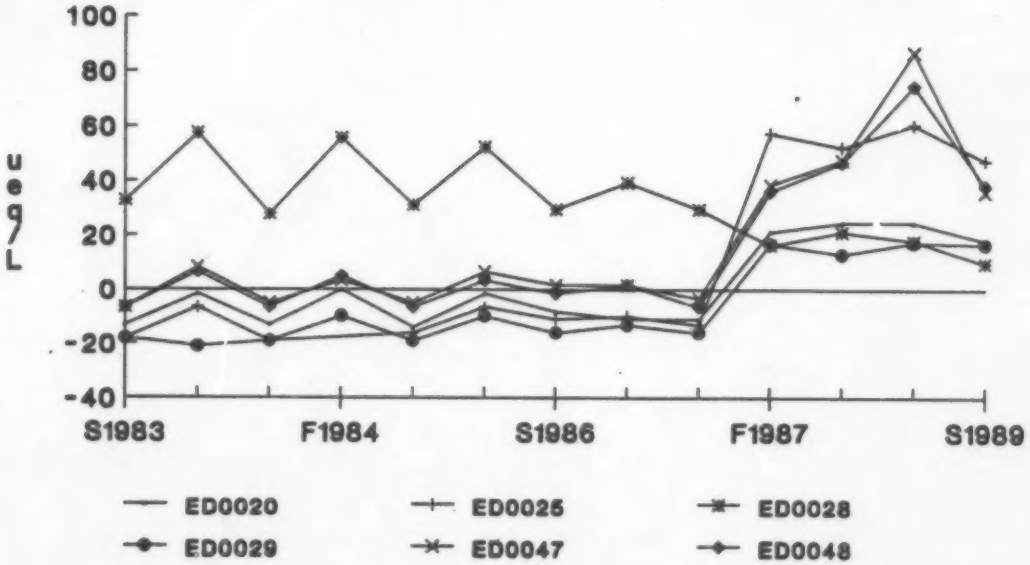
ALK
CLUSTER 2 NEWFOUNDLAND



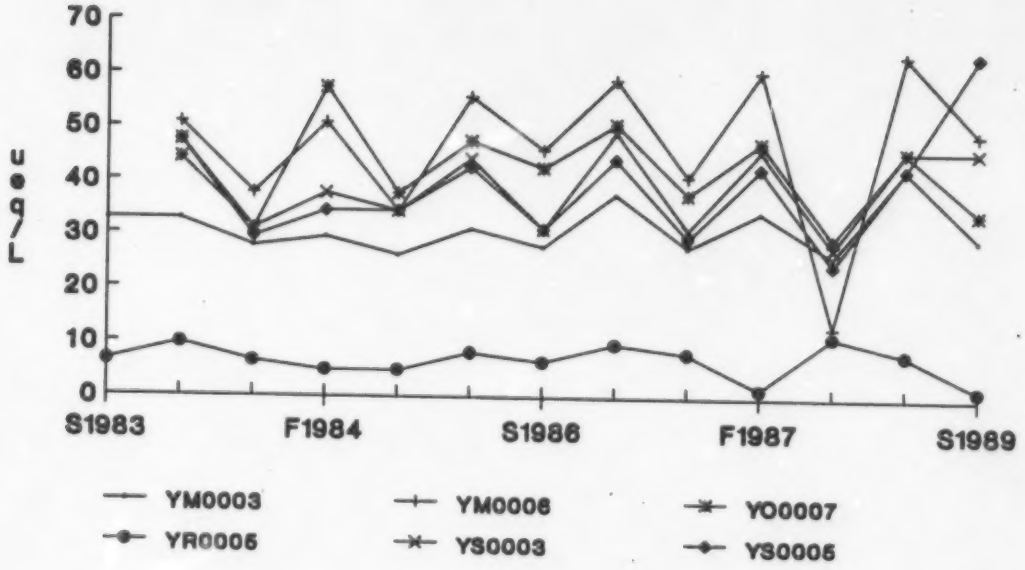
ALK
CLUSTER 3A NOVA SCOTIA



ALK
CLUSTER 3B NOVA SCOTIA



ALK
CLUSTER 3A NEWFOUNDLAND



ALK
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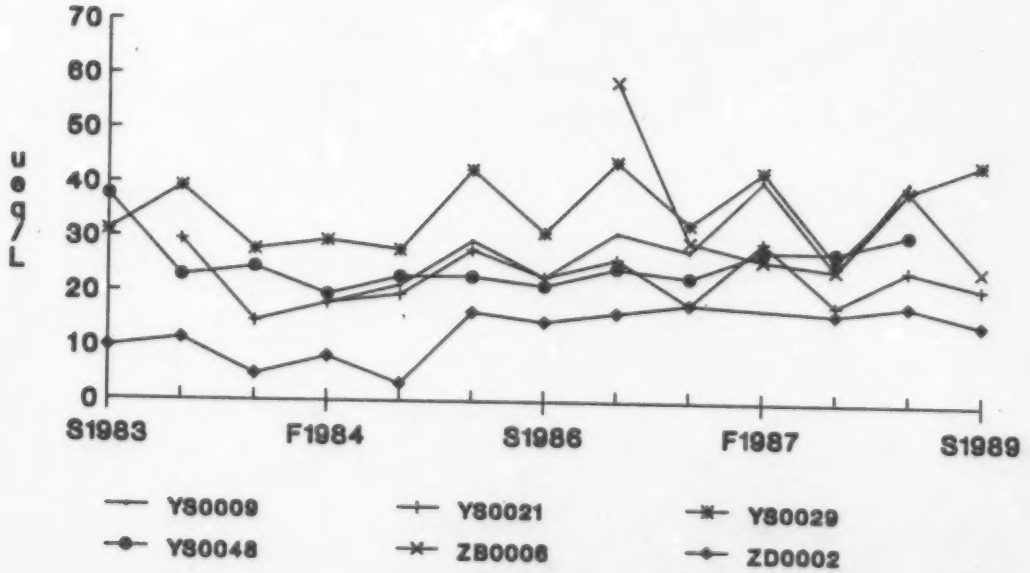
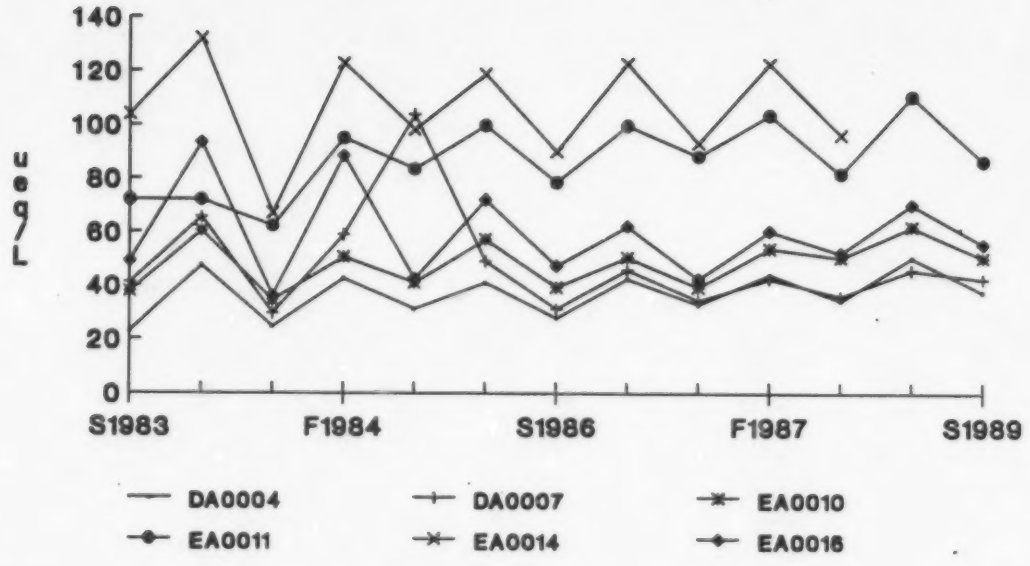
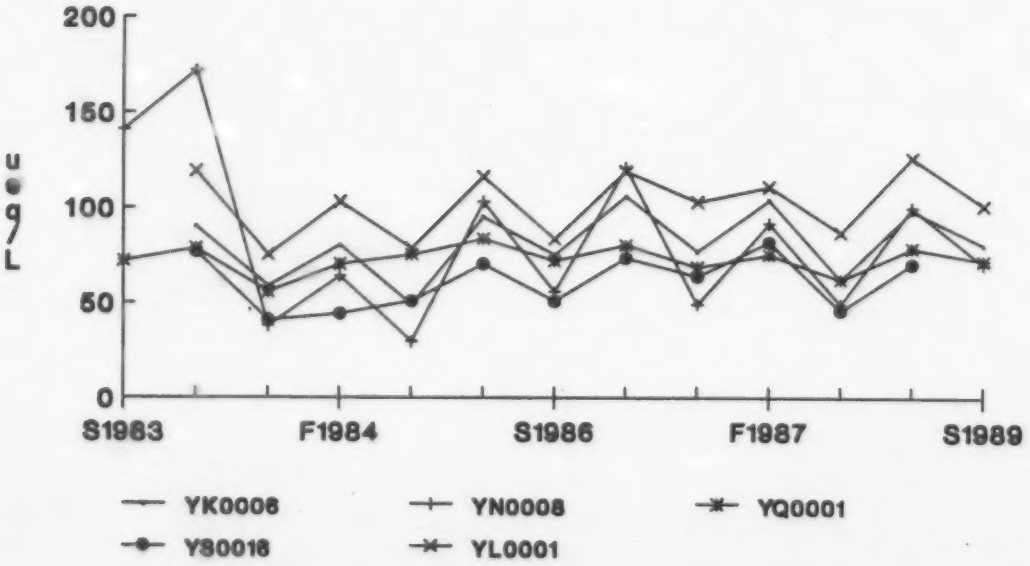


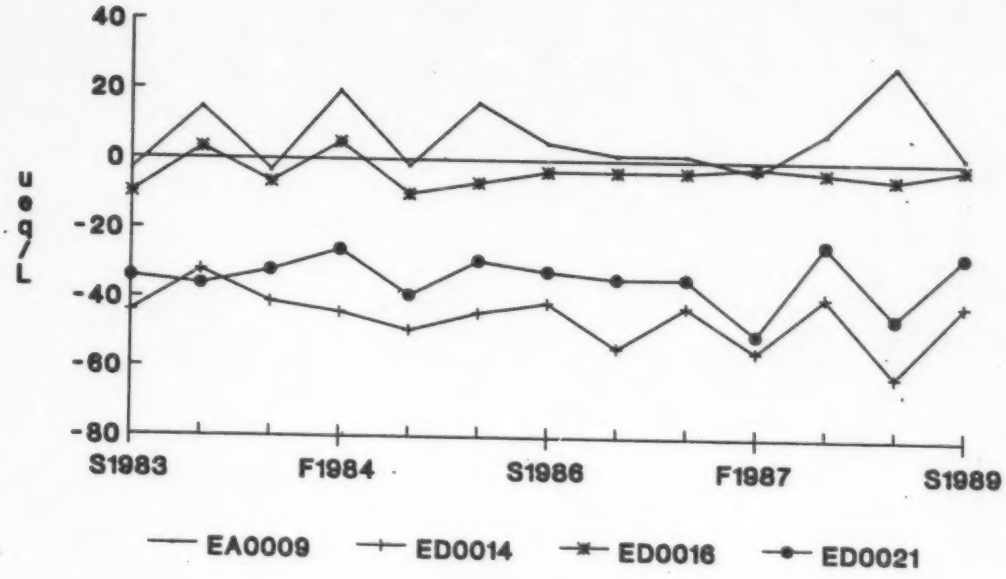
ALK
CLUSTER 4 NOVA SCOTIA



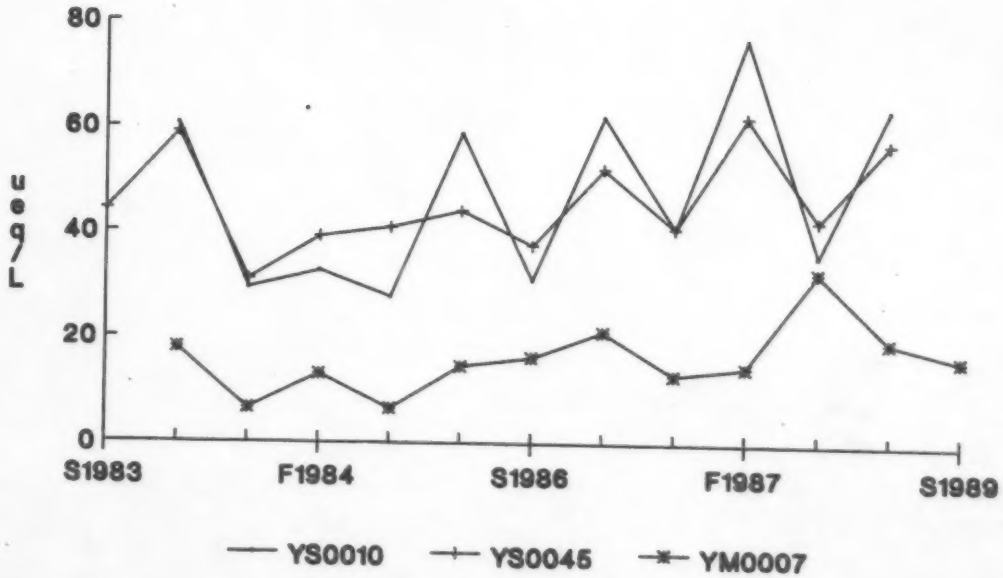
ALK
CLUSTER 4 NEWFOUNDLAND



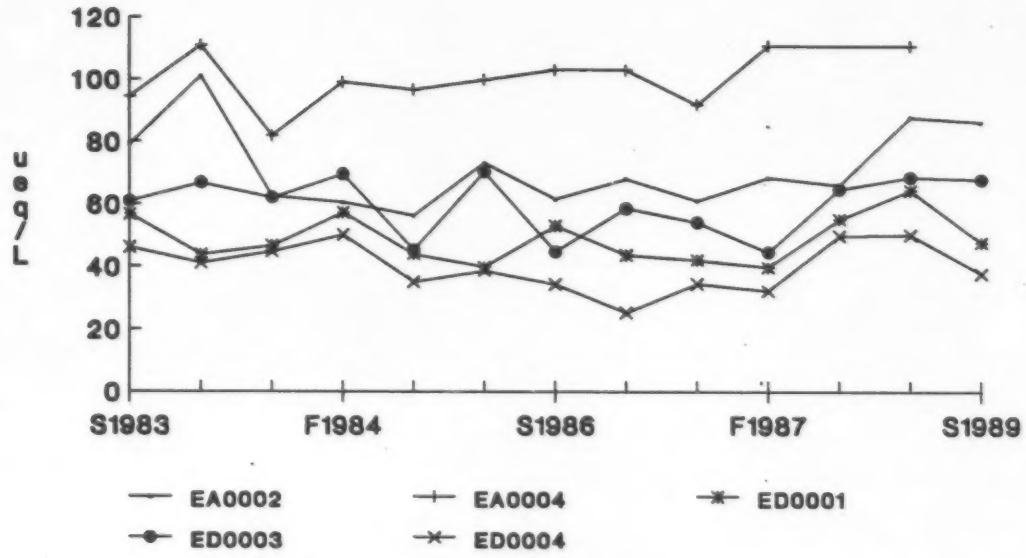
ALK
CLUSTER 5 NOVA SCOTIA



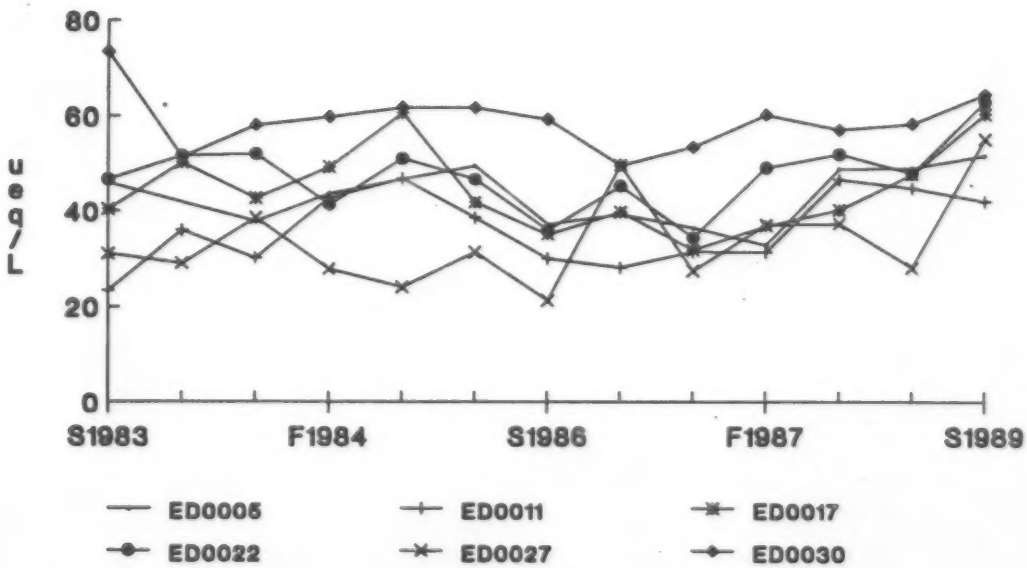
ALK
CLUSTER 5 NEWFOUNDLAND



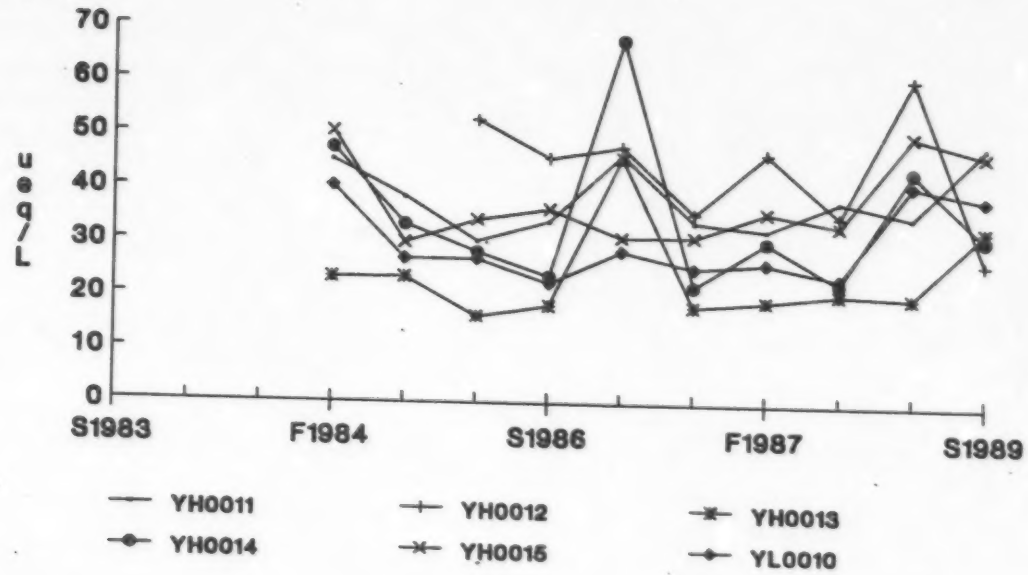
Ca, Mg, K
CLUSTER 1A NOVA SCOTIA



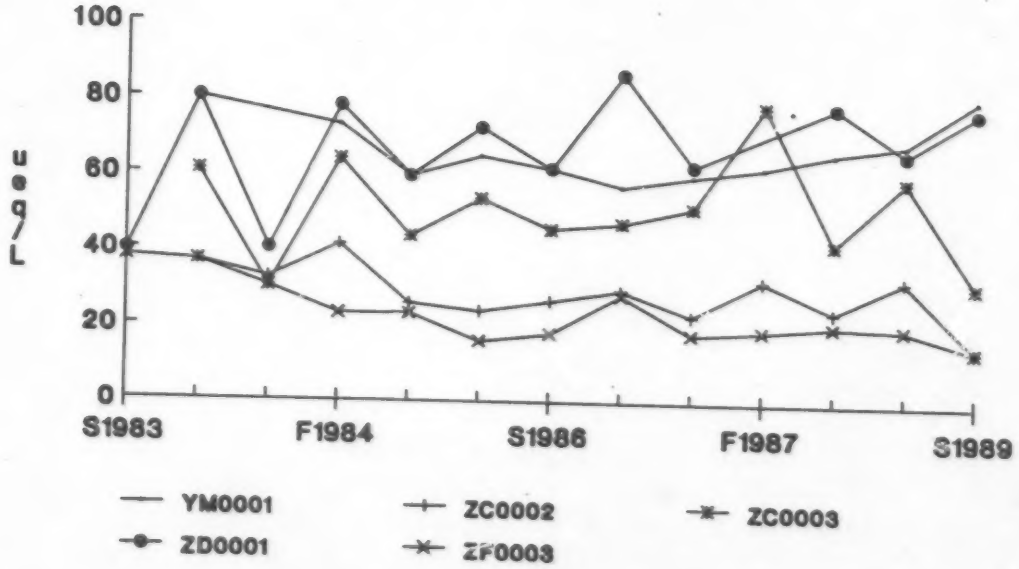
Ca, Mg, K
CLUSTER 1B NOVA SCOTIA



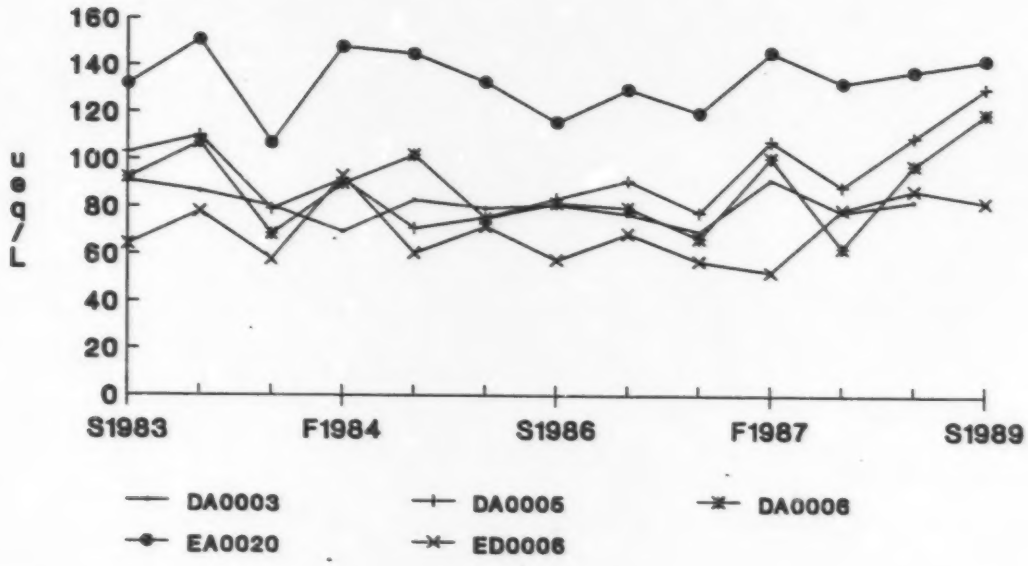
Ca, Mg, K
CLUSTER 1A NEWFOUNDLAND



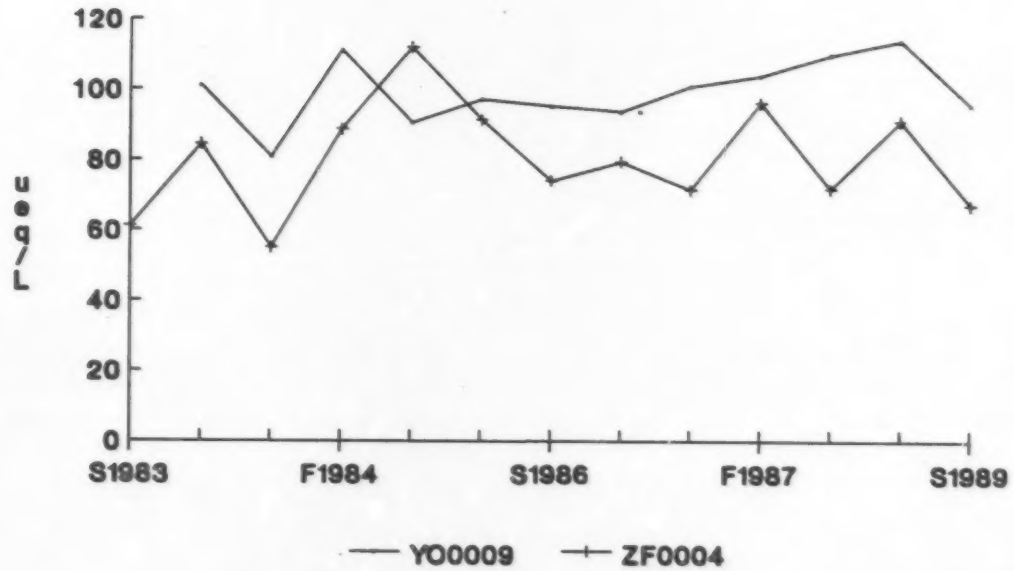
Ca, Mg, K
CLUSTER 1B NEWFOUNDLAND



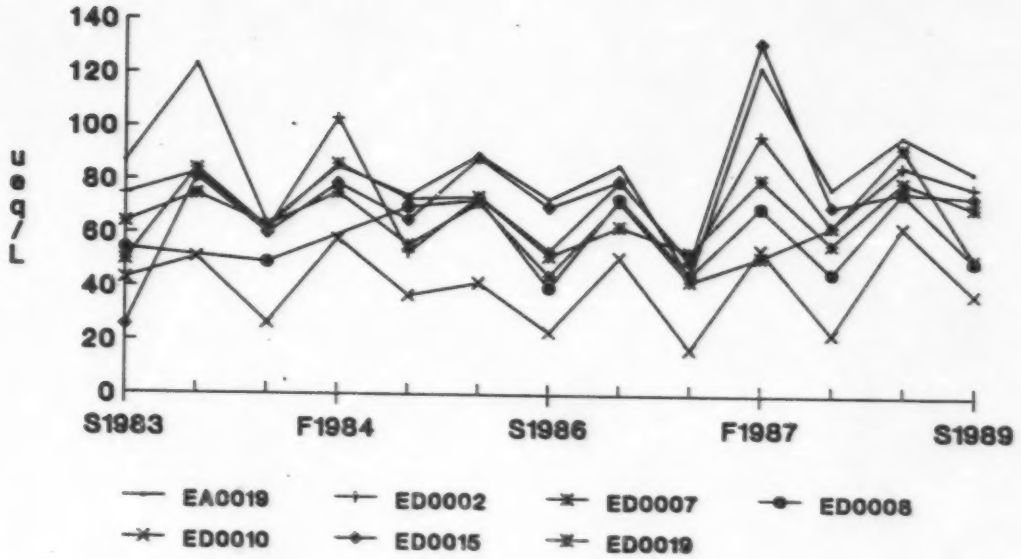
Ca, Mg, K
CLUSTER 2 NOVA SCOTIA



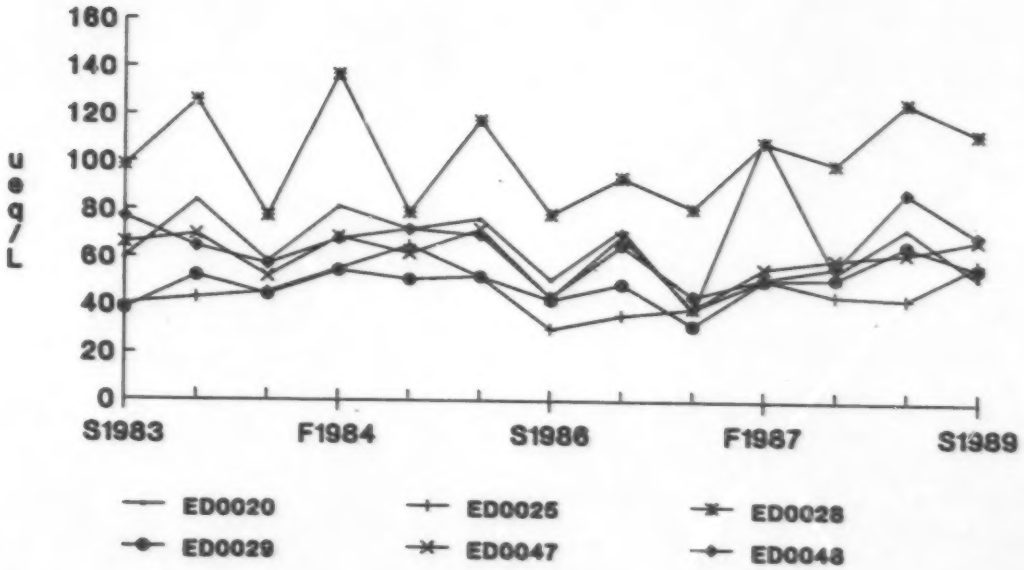
Ca, Mg, K
CLUSTER 2 NEWFOUNDLAND



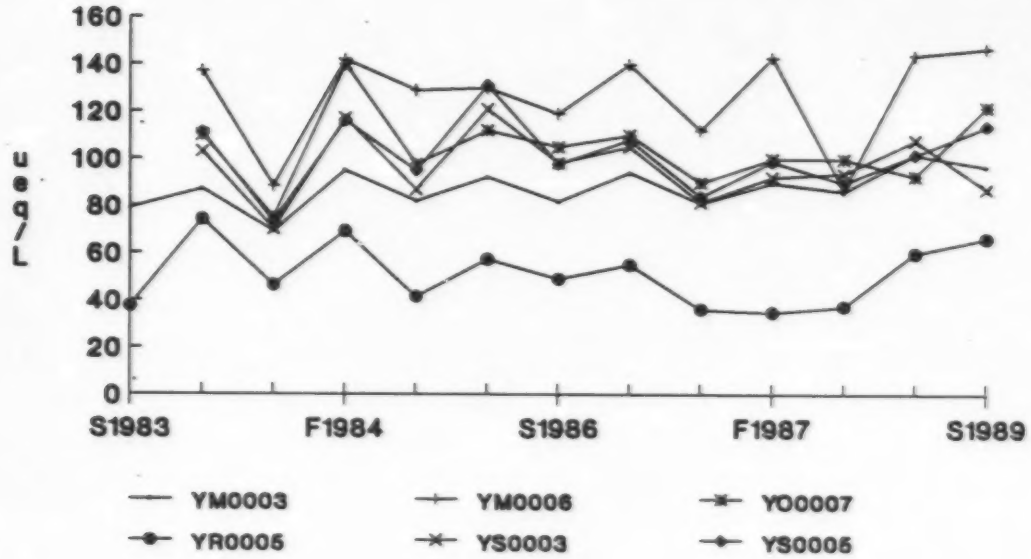
Ca, Mg, K
CLUSTER 3A NOVA SCOTIA



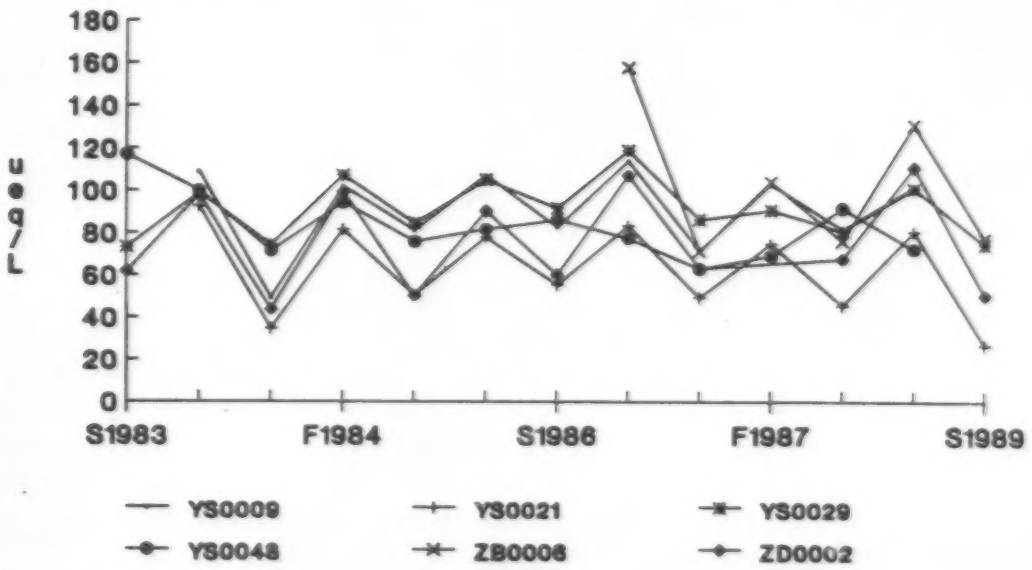
Ca, Mg, K
CLUSTER 3B NOVA SCOTIA



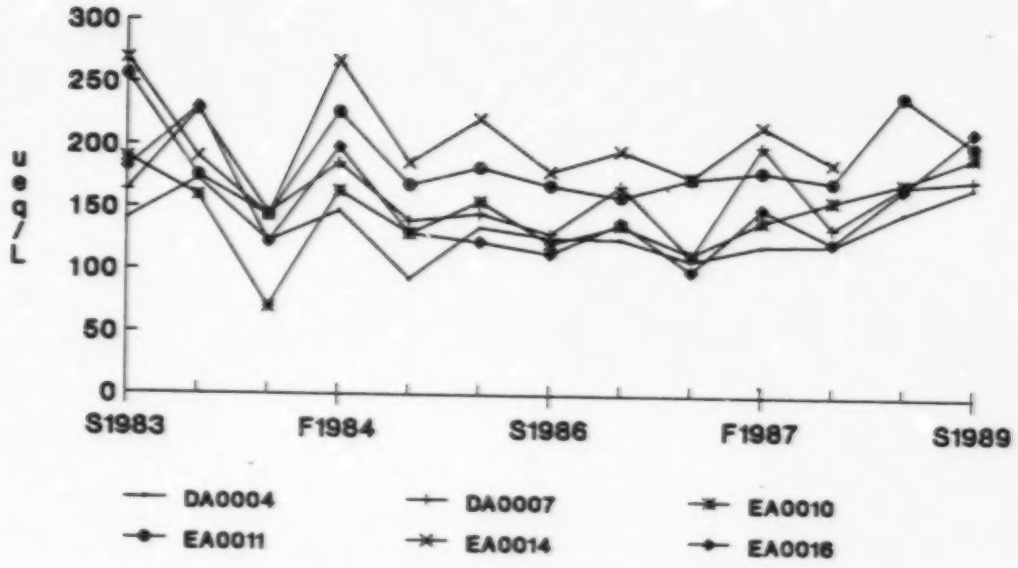
Ca, Mg, K
CLUSTER 3A NEWFOUNDLAND



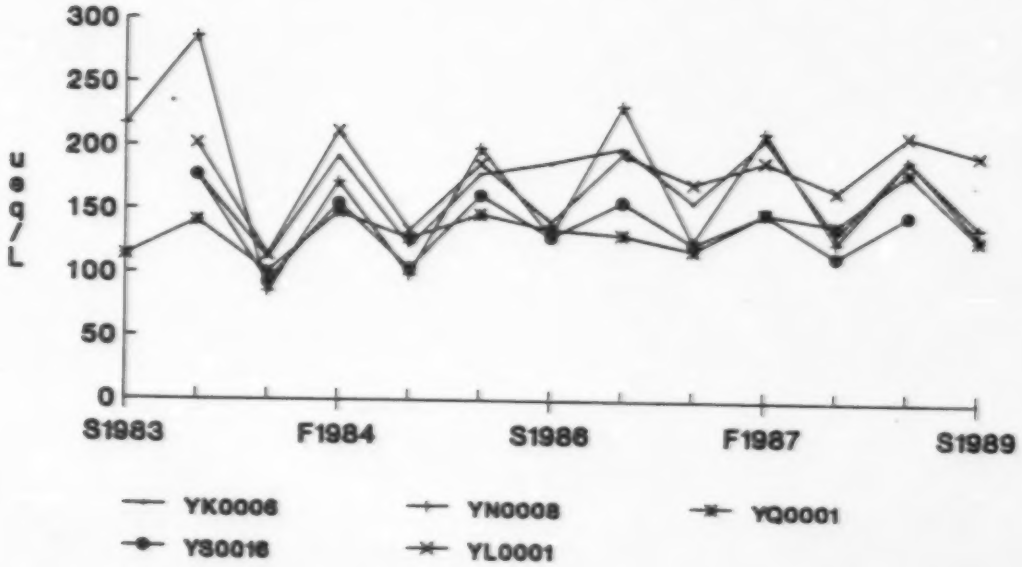
Ca, Mg, K
CLUSTER 3B NEWFOUNDLAND



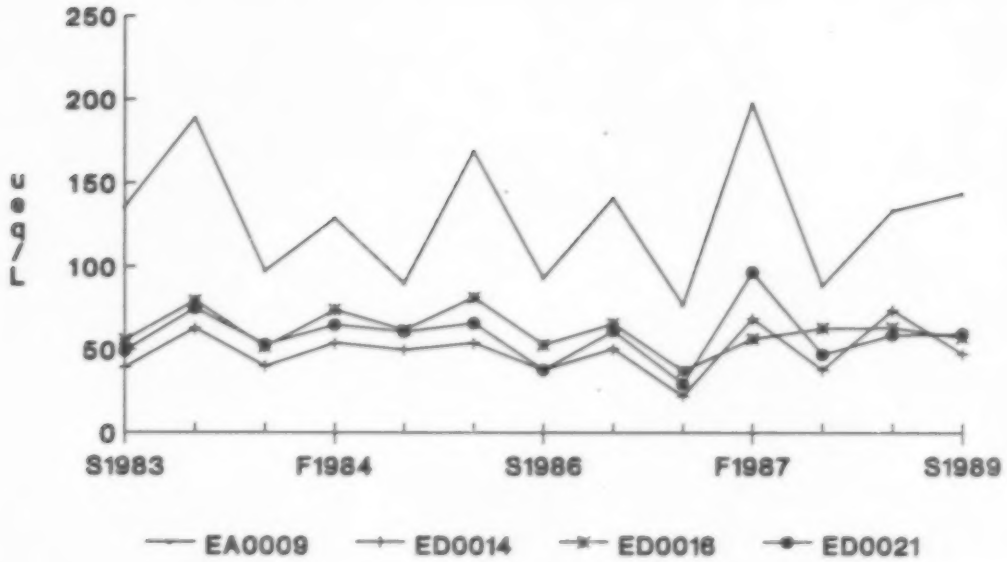
Ca, Mg, K
CLUSTER 4 NOVA SCOTIA



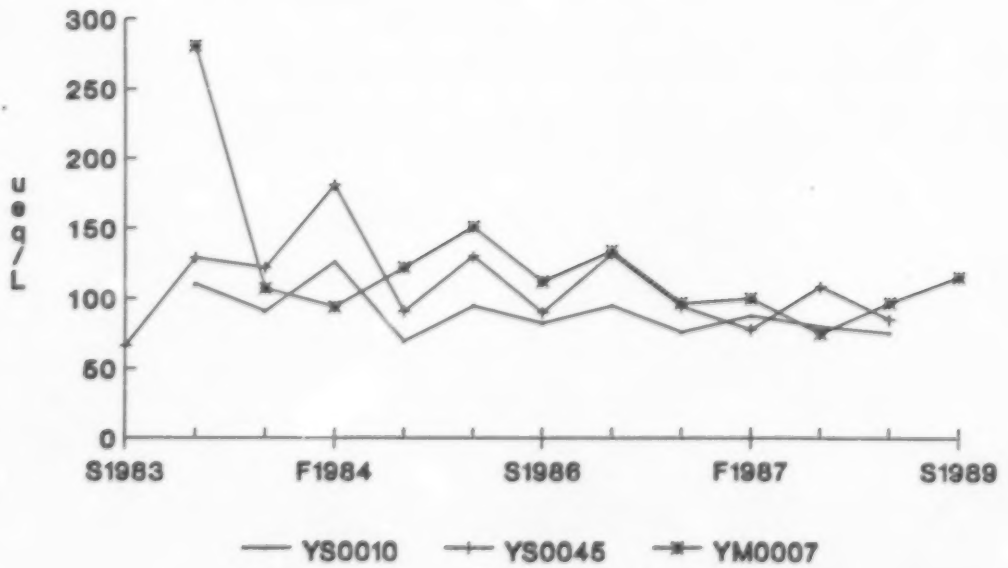
Ca, Mg, K
CLUSTER 4 NEWFOUNDLAND



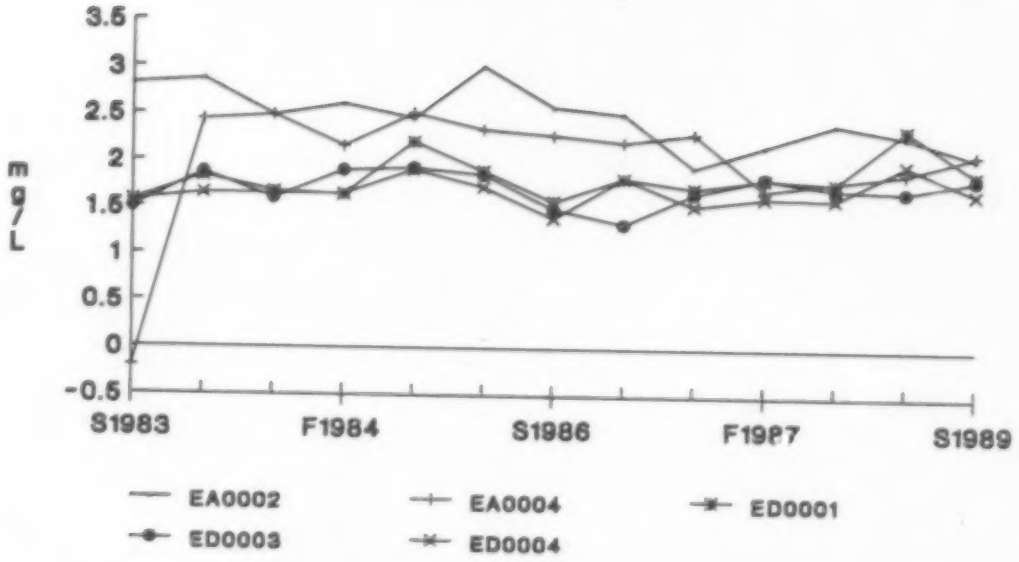
Ca, Mg, K
CLUSTER 5 NOVA SCOTIA



Ca, Mg, K
CLUSTER 5 NEWFOUNDLAND



SSS04
CLUSTER 1a NOVA SCOTIA



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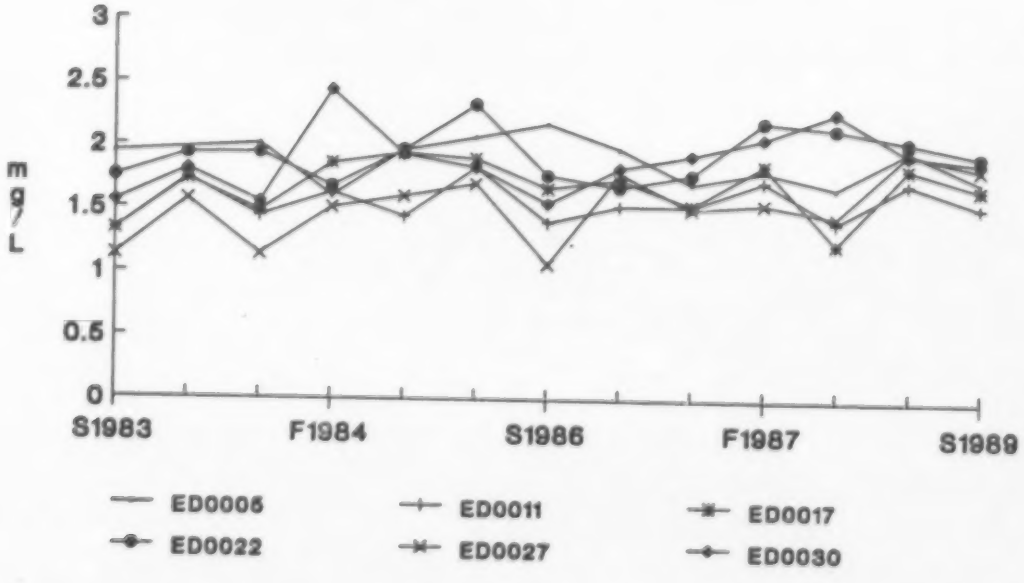
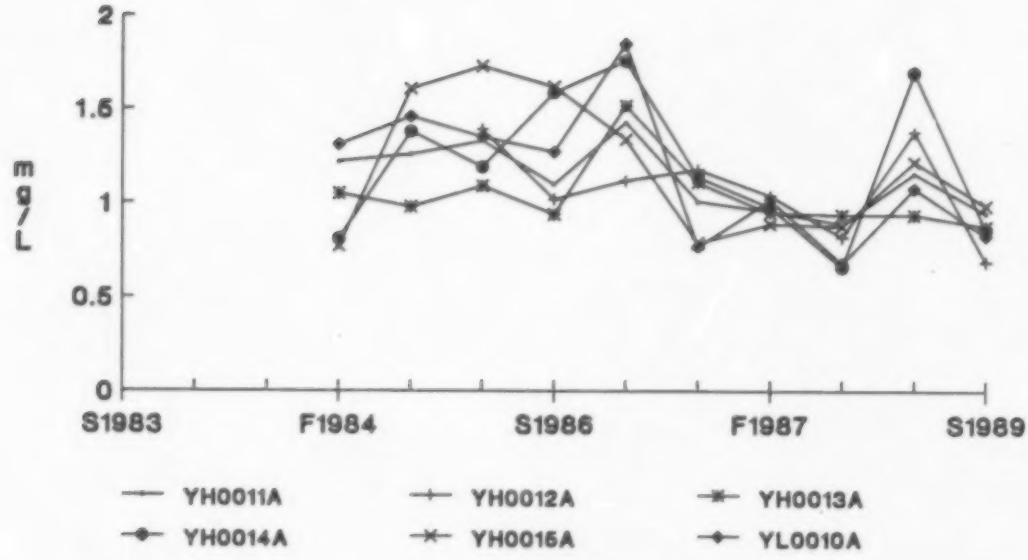


SSS04
CLUSTER 1a NEWFOUNDLAND



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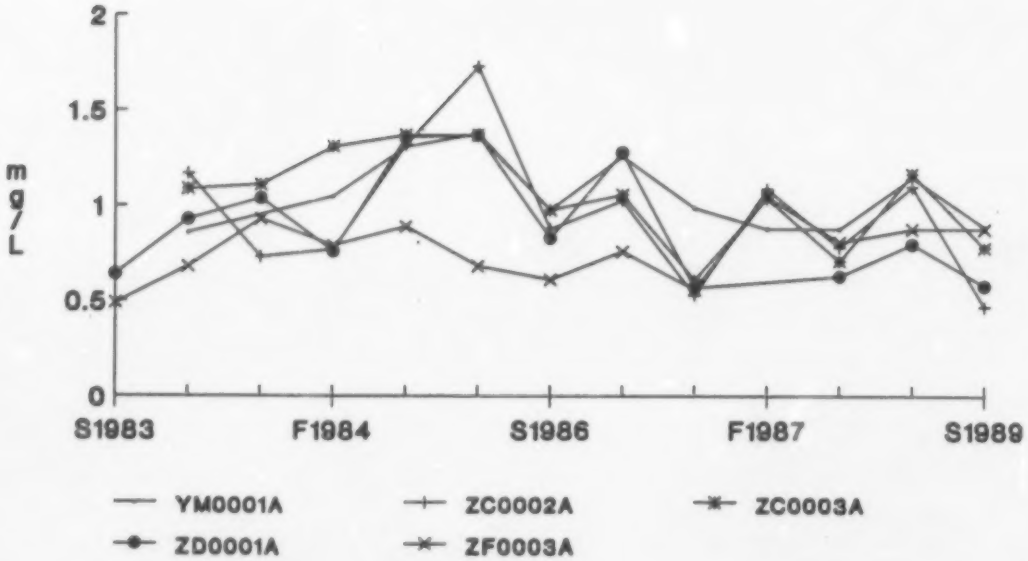
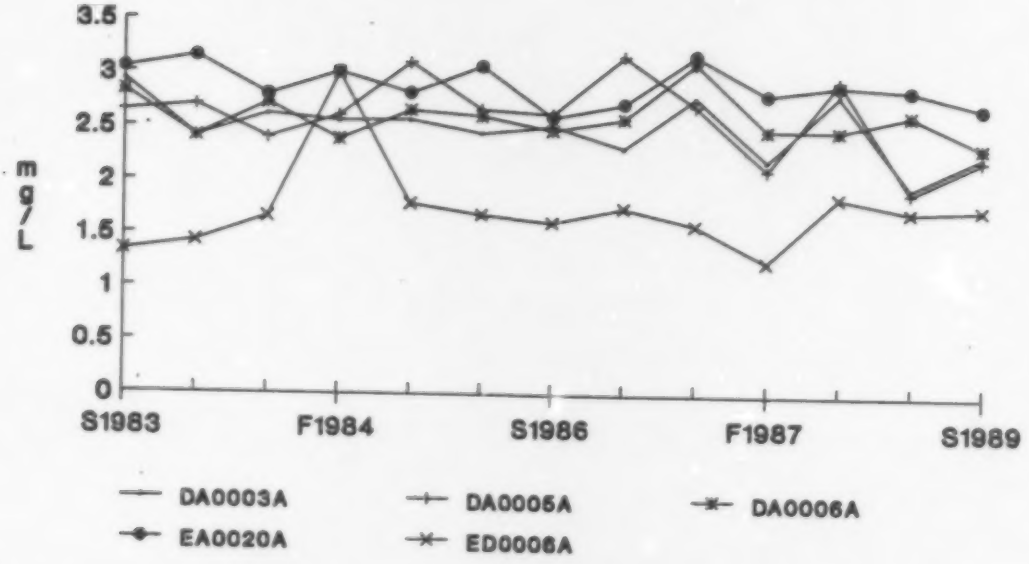
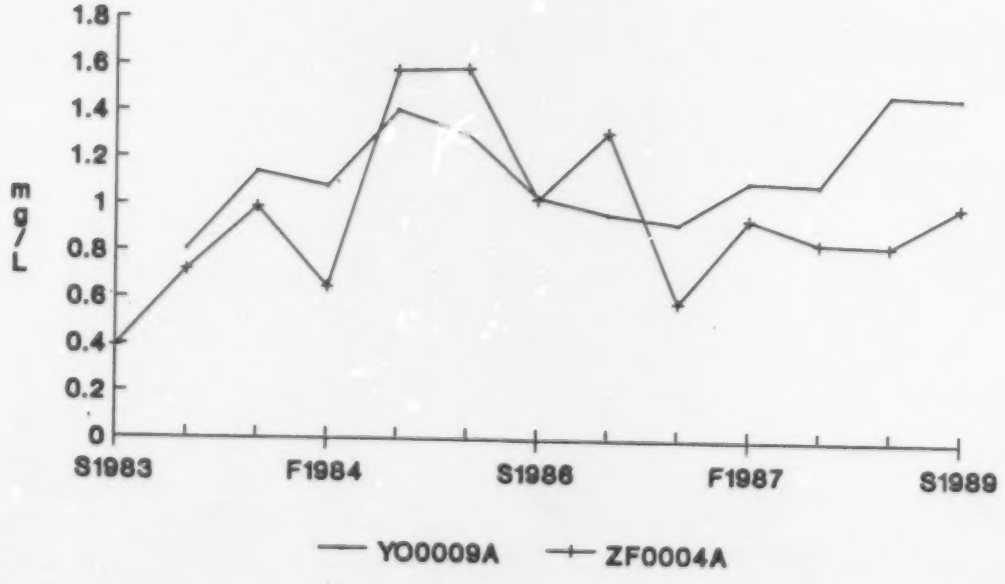
CLUSTER 1b NEWFOUNDLAND



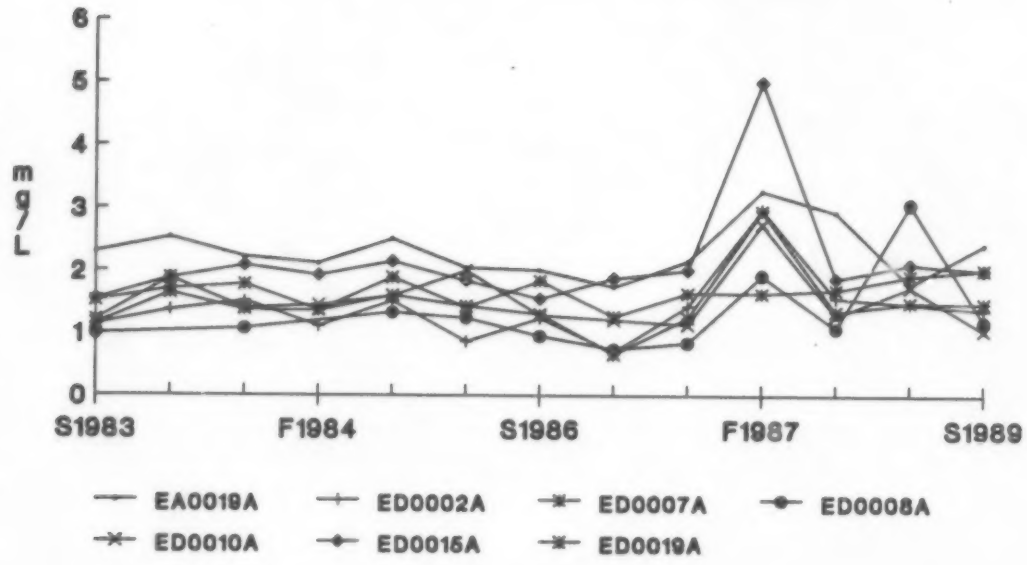
SSS04
CLUSTER 2 NOVA SCOTIA



SSS04
CLUSTER 2 NEWFOUNDLAND



SSS04
CLUSTER 3a NOVA SCOTIA



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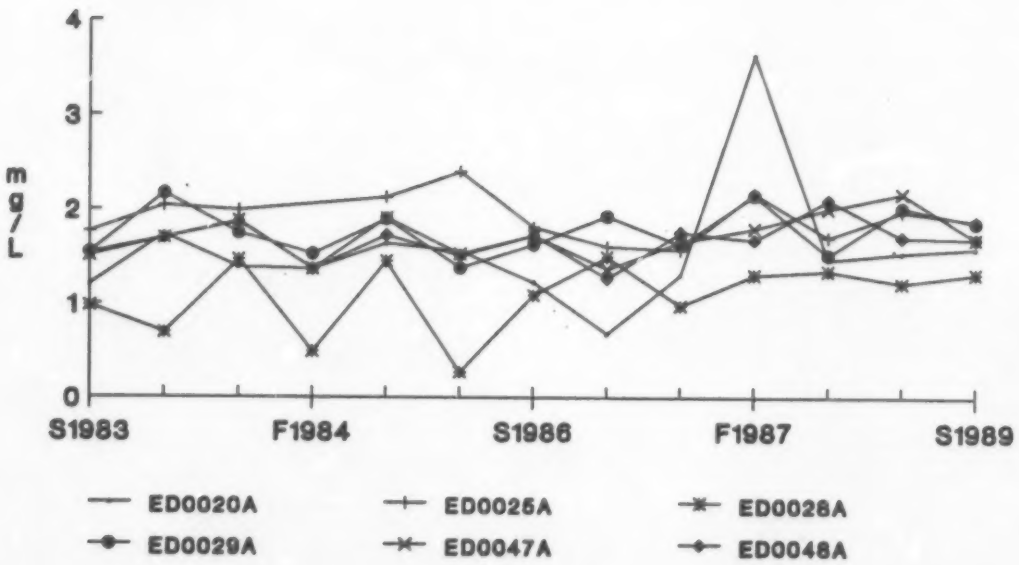
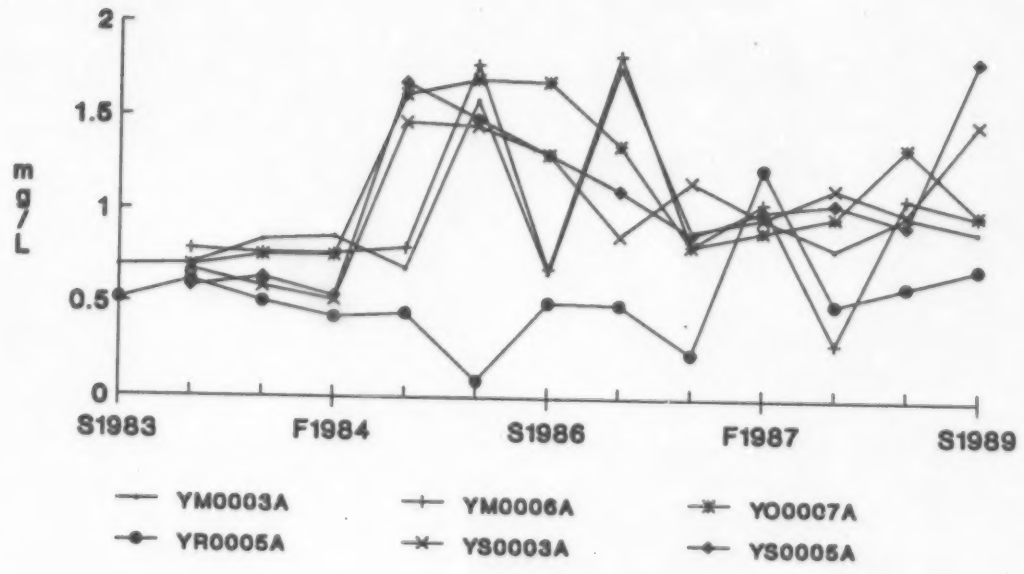
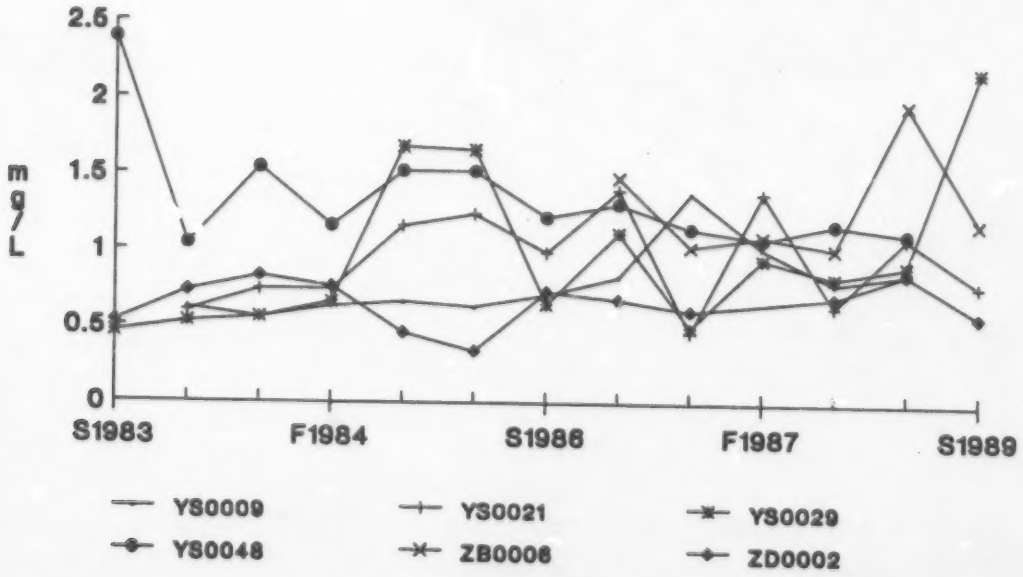


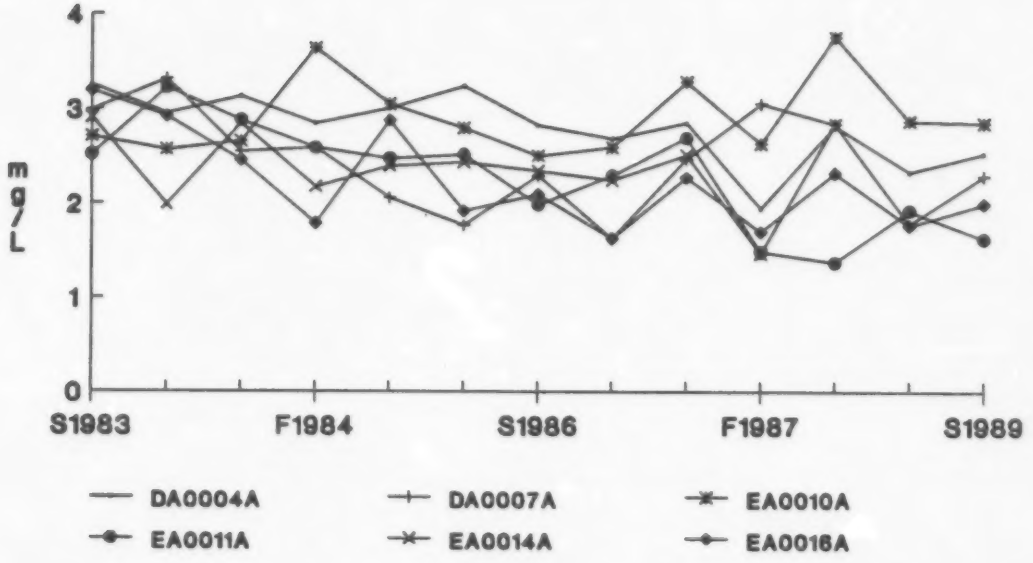
SSS04
CLUSTER 3a NEWFOUNDLAND



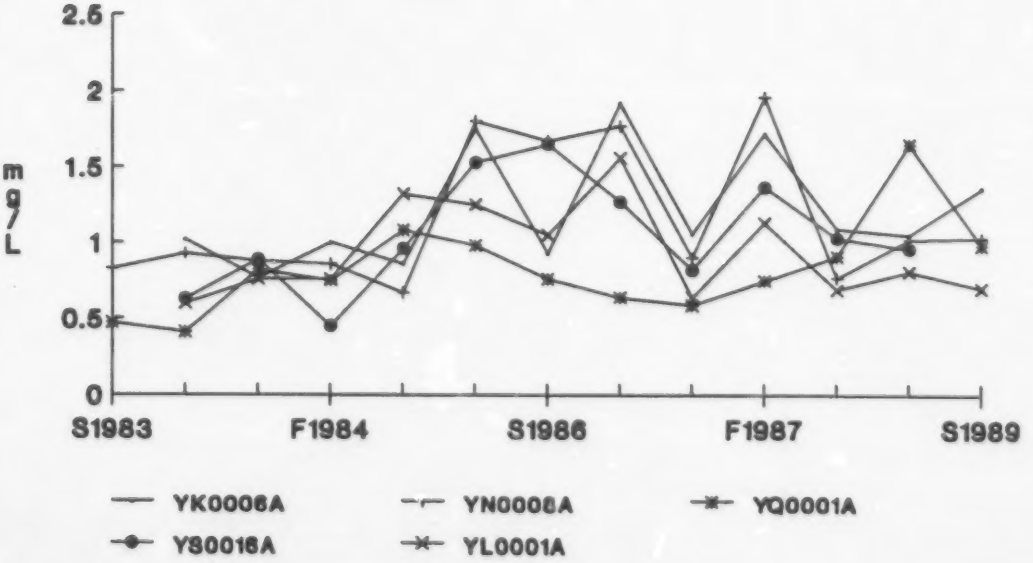
SSS04
CLUSTER 3B NEWFOUNDLAND



SSS04
CLUSTER 4 NOVA SCOTIA



SSSO4
CLUSTER 4 NEWFOUNDLAND



SSS04
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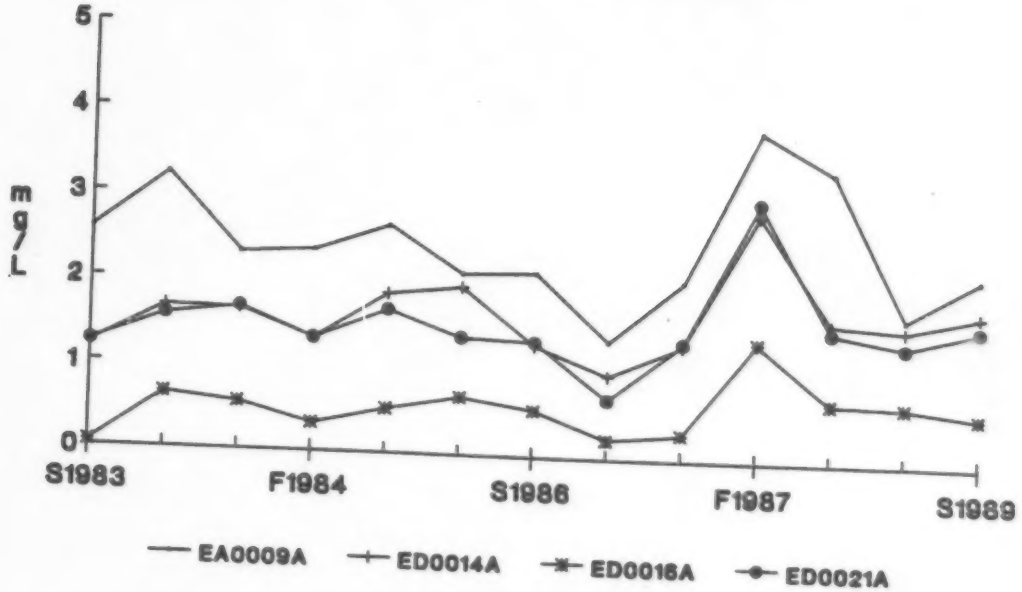

SSSO4
CLUSTER 5 NEWFOUNDLAND